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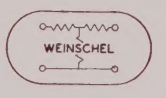
INCLUDING CALIBRATION PROCEDURES
FOR
BOLOMETER PREAMPLIFIER MODEL BA-1D

Weinschel Engineering

KENSINGTON, MARYLAND



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INSTRUCTION MANUAL
INCLUDING CALIBRATION PROCEDURES
FOR
BOLOMETER PREAMPLIFIER MODEL BA-1D

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IM #1R

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Weinschel Engineering

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Research & Development Calibration Service

The Weinschel Engineering Bolometer Preamplifier, Model BA-1C, has been superseded by the Model BA-1D. This instruction manual was written for the BA-1C. However, the differences are minor and are described below.

The BA-1D is designed to operate from either 115 volt 50-60 cps nominal line voltage or 220 volt 50-60 cps nominal line voltage. A red "CAUTION" label affixed to the rear of the chassis indicates the voltage for which the unit was wired prior to shipment from the factory. The primary voltage connections may be changed in the field by removing the bottom cover and rearranging the two metal jumpers on the terminal strip (TS-2) located on the inside of the back edge of the chassis. For 115 volt operation, the jumpers should be placed between terminals 1 and 2, and 3 and 4. For 220 volt operation, the jumpers should both be placed between terminals 2 and 3. These connections are shown on the Model BA-1D Schematic Diagram (Dwg. C110-185) which is attached to this addendum.

The only other change is in the Parts List. The new power transformer has been designated as Weinschel Part No. 40-74.

In all other respects, the two models are identical.

Addendum, IM #1R
April 1962
Attachment: Dwg. C110-185

Weinschel Engineering
Kensington, Maryland

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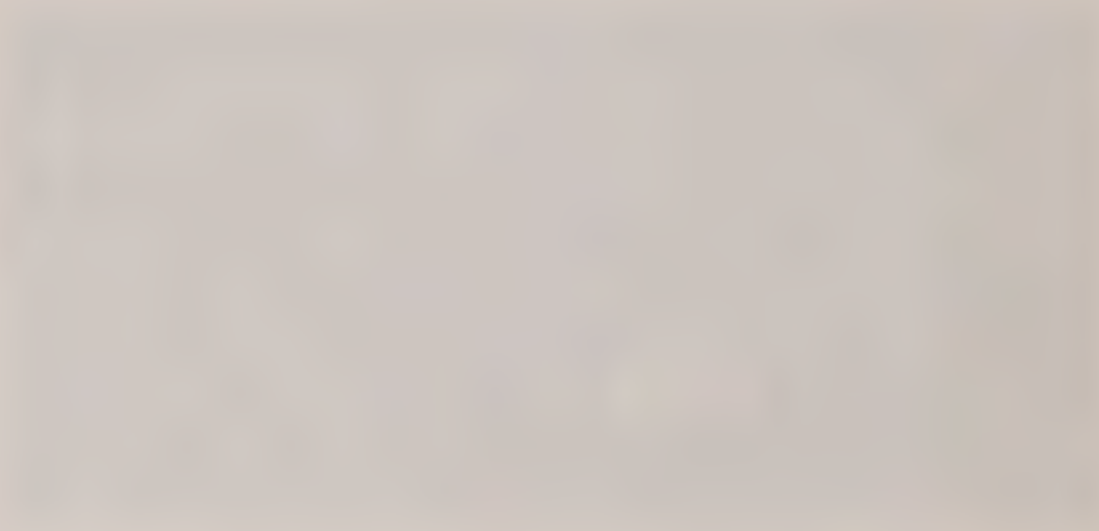
Figure 1.1. Bolometer Preamplifier Model BA-1C, Front Panel



SECTION I

GENERAL INTRODUCTION

1.1 SCOPE OF MANUAL

This manual covers the description, theory of operation, operating instructions, maintenance, and parts breakdown for Bolometer Preamplifier Model BA-1C, Serial Number 146 and above, manufactured by Weinschel Engineering Co., Inc., Kensington, Maryland.

1.2 PURPOSE OF EQUIPMENT

Bolometer Preamplifier Model BA-1C is designed for general use in close tolerance measurements of rf power level ratios when used with recommended square-law detectors and other associated equipments. Typical examples of rf power level measurements include the determination of insertion losses, amplifier gains, antenna patterns, and standing-wave ratios.

1.3 UNPACKING AND PREPARATION FOR USE

Bolometer Preamplifier Model BA-1C is shipped in a double container with three inches of packing between the inner and outer cases. Normal care should be exercised in removing the equipment from the case and in removing the packing material. There should be no loose parts with the exception of the line cord and the Instruction Manual. The tubes are shipped in place. The following inspections should be performed immediately after unpacking; if damage is found, notify the shipping company immediately.

a. Inspect the equipment for mechanical damage.

b. Remove the bottom chassis cover and visually examine the interconnecting leads between the floating sub-chassis and the main chassis to be sure no connections have been broken in transit.

c. Check the tube positions and insure that all tubes are seated firmly.

d. Check that the fuse is not broken.

1.4 PHYSICAL DESCRIPTION OF EQUIPMENT

(See Figure 1.1.)

The Bolometer Preamplifier is designed for standard relay rack mounting. All operating controls are located on the front panel and are clearly identified as to function by etched designations on the black crackle-finish front panel background. Also located on the front panel are the bolometer current monitoring meter, input and output coaxial connectors, and the primary power indicator lamp.

The overall dimensions of the Bolometer Preamplifier are 8-3/4 inches in height, 19 inches in width, and 13-1/2 inches in depth. The net weight of the equipment is 20 pounds; packed for shipment, 38 pounds.

1.5 ELECTRICAL DESCRIPTION OF EQUIPMENT

The Bolometer Preamplifier Model BA-1C is a high-gain low-noise amplifier which is tuned to 1000 cps; Figure 1.2 shows the circuit in block diagram form. The input of the Bolometer Preamplifier is connected to a bolometer or crystal square-law detector and the output to a high-impedance measuring device such as a null detector or vacuum-tube voltmeter. The input circuit consists of a step-up transformer, which provides the proper load impedance for either a bolometer or crystal detector, and a bolometer bias circuit. The af signal input is amplified by a high-gain amplifier to provide a suitable output signal level. Feedback from the amplifier is applied through a tuned audio filter network to the input circuit. The filter network controls the narrow pass band and consequently the low noise level of the amplifier. The complete schematic diagram appears in Figure 1.3.

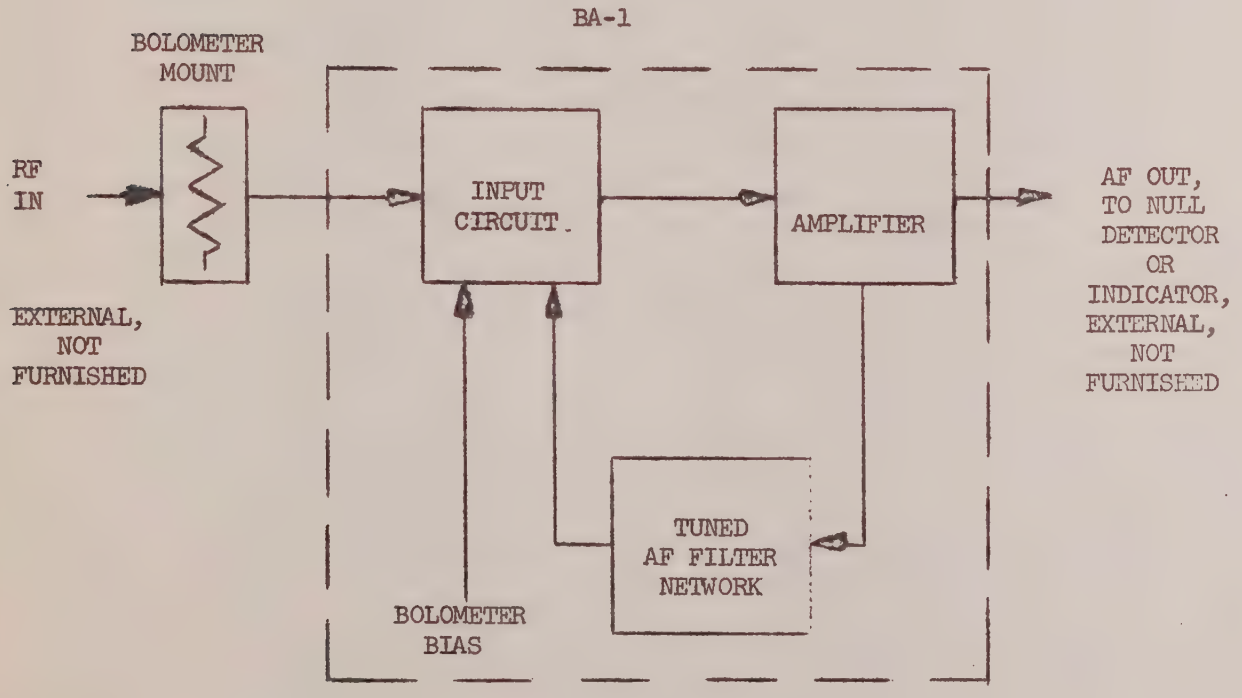


Figure 1.2. Block Diagram, Bolometer Preamplifier Model BA-1C

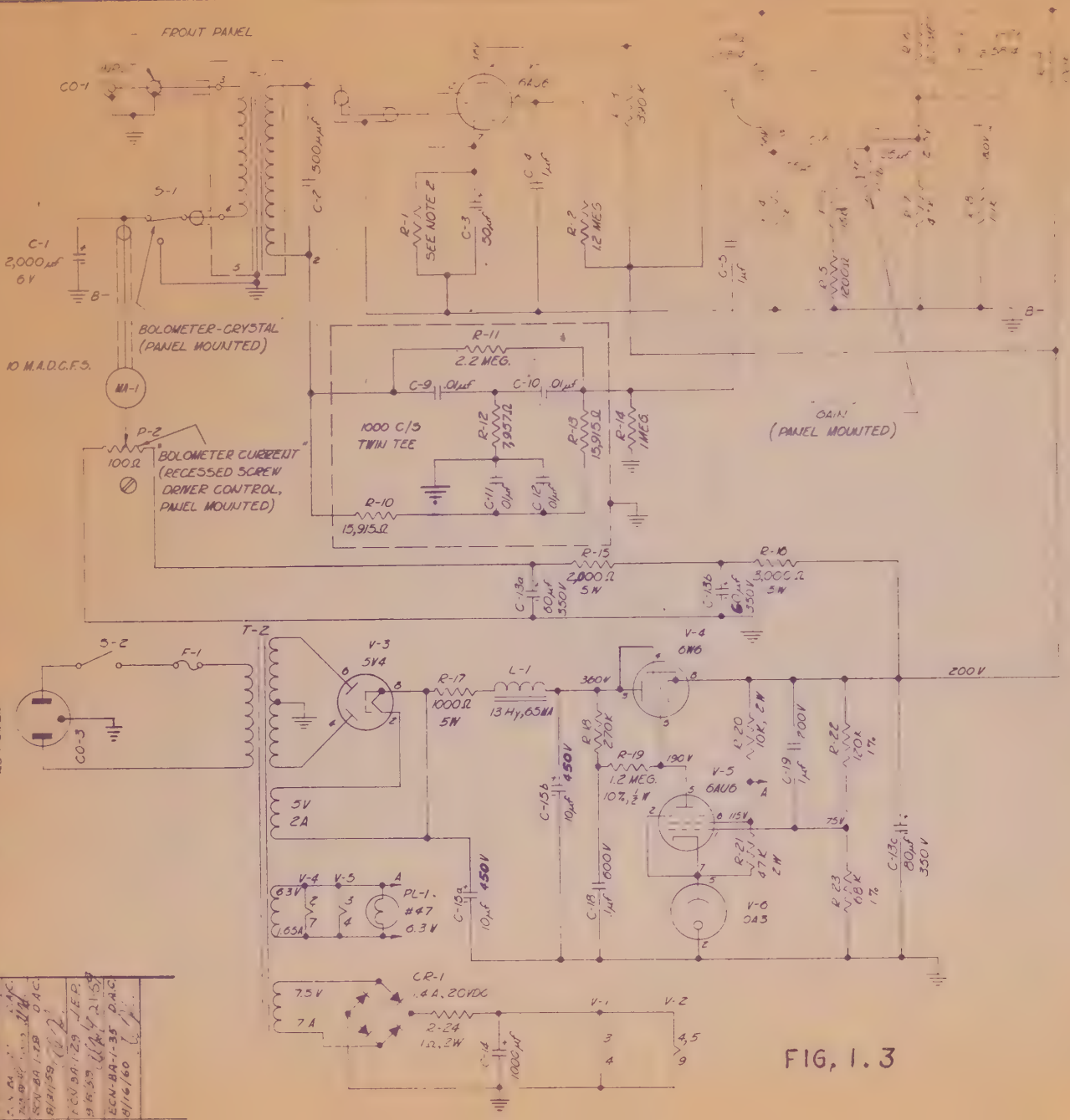


FIG. 1.3

NOTES:
1. C-9, C-10, C-11 AND C-12 TO BE SELECTED FOR 1000 CPS.
2. R-1 TO BE SELECTED FOR CORRECT GAIN WITH TYPICAL VALUE = 2.2 K.

REVISIONS

	6/21/59	ECN-BA-1-28 D.A.C.
	12/9/59	ECN-BA-1-35 D.A.C.
	8/16/60	

BASED ON ASSY DRWG 84-

Weinschel Engineering

SCHEMATIC
BOLOMETER PRE-AMPLIFIER

MATERIAL

DIMENSIONS ARE IN INCHES TOLERANCES

SCALE

IM # IR 6/61

1.6 FUNCTION OF OPERATING CONTROLS AND INDICATORS

The functions of the operating controls and indicators (all located on the front panel) are listed in Table 1.1.

TABLE 1.1
Function of Operating Controls and Indicators

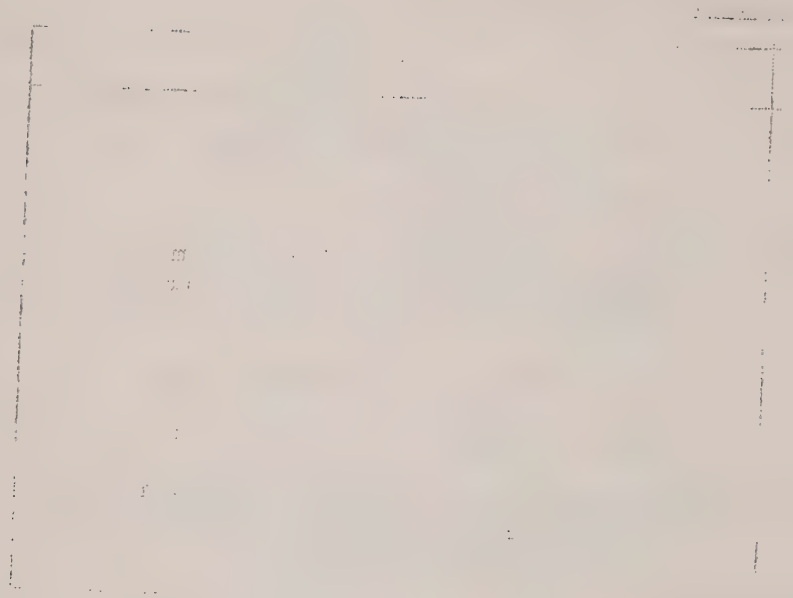
Item	Function
ON - OFF toggle switch	Controls application of ac power
Power on indicator	Indicates power status
CRYSTAL - BOLO. selector switch	Disconnects bolometer bias circuit from input when a crystal diode is used as the square-law detector
BOLOMETER CURRENT ADJUST	Sets bolometer dc bias current level
BOLOMETER CURRENT meter	Indicates magnitude of bolometer dc bias current
GAIN controls (coaxially mounted)	Controls voltage gain of amplifier. Coarse control has approximately 14:1 range and fine control approximately 5 percent

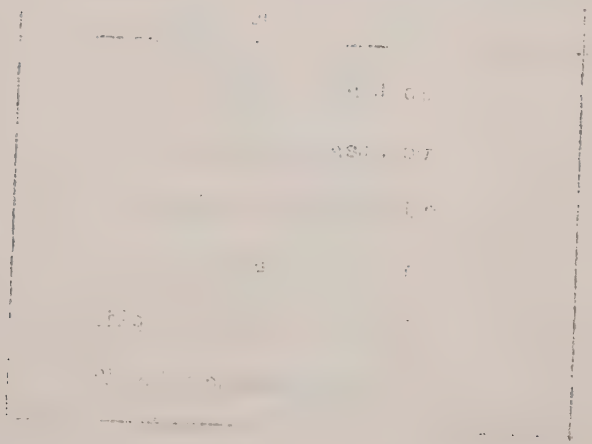
1.7 ELECTRON TUBE AND ELECTRICAL CONNECTOR COMPLEMENT

The electron tube complement of the Bolometer Preamplifier appears in Table 1.2; the electrical connector complement is listed in Table 1.3.

TABLE 1.2
Electron Tube Complement

Symbol	Type	Use
V1	6AU6	Input amplifier
V2	5814	Two stage amplifier
V3	5V4	Full wave rectifier
V4	6W6	Series regulator
V5	6AU6	Voltage regulator amplifier
V6	OA3/VR-75	Voltage reference for V5





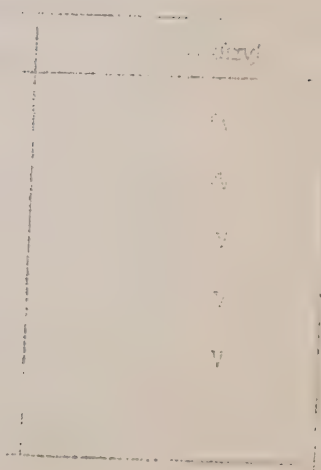


TABLE 1.3
Electrical Connector Complement

Item	Location	Type
INPUT	Front panel	BNC female
OUTPUT	Front panel	BNC female
Power	Rear of chassis	Standard 115-volt 3-wire recessed male cap

1.8 ELECTRICAL CHARACTERISTICS

The complete electrical characteristics of the Bolometer Preamplifier are presented in Table 1.4.

TABLE 1.4
Electrical Characteristics, Bolometer Preamplifier Model BA-1C

Characteristic	Descriptive Data
Power requirement:	105 to 125 volts, 60 cps, 40 VA
Ambient temperature:	15 to 35 degrees C (59 to 95 degrees F)
Maximum output voltage:	30 volts rms into a 1 megohm load
Input impedance:	30,000 ohms ± 20 percent
External source impedance:	For use with a bolometer having a dc resistance between 50 and 200 ohms or video crystals requiring no dc bias current
Output impedance:	Less than 100,000 ohms
External load impedance:	Greater than 1 megohm required for minimum distortion
Frequency Audio: Radio:	 1000 ± 2 cps Any for which bolometers, crystals, or other required accessories are available
Audio frequency bandwidth:	Not less than 25 nor more than 35 cps between 3 db points
Voltage gain Magnitude:	 At least 10,000 at full gain with a minimum external output load of 1 megohm

TABLE 1.4 (Continued)
Electrical Characteristics, Bolometer Preamplifier Model BA-1C

Characteristic	Descriptive Data
Voltage gain (continued) Stability:	Will not change more than ± 0.1 db (rf) for a line voltage change from 105 to 125 volts
Linearity (with voltage gain adjusted to 10,000) Up to 3 volts output:	Within 0.25%, or departure from linearity of not more than 0.01 db (rf) if input signal is derived from square-law detector
Up to 30 volts output:	Within 1.2%, or departure from linearity of not more than 0.05 db (rf) if input signal is derived from square-law detector
Equivalent noise:	Less than 30×10^{-9} volts rms referred to the input when connected to a 200-ohm shielded wirewound resistor
Bolometer bias current:	Adjustable from 0 to 10 ma dc. The bolometer may be disconnected or connected and the power switched on or off without damage to the bolometer

1.9 PRE-OPERATING PREPARATIONS AND PRECAUTIONS

Set the front panel ON-OFF toggle switch to the OFF position. Plug the line cord into a stable 115-volt, 60-cps power source capable of supplying 40 VA power and maintaining the line voltage within operating limits at all times. It is recommended that the Bolometer Preamplifier be operated from a well-regulated power source, such as a Sorensen AC Voltage Regulator.

NOTE

When a line voltage regulator is used, it should be removed at least 6 feet from the bolometer mount and bolometer preamplifier.

The Bolometer Preamplifier should not be mounted in the same relay rack as the af modulator for the rf source. Although the equipment is well shielded, do not locate it where it will be operating in or near high-intensity af or rf fields.

The coaxial input cable from the bolometer mount to the Bolometer Preamplifier's INPUT jack should be kept as short as possible. Under no circumstances should the coaxial input cable exceed 3 feet in length. Avoid an arrangement of shielded cables which form a ground loop.

1.10 PROCEDURE FOR STARTING EQUIPMENT

The procedure for starting the equipment is outlined below and should be performed in the order shown:

a. Set BOLOMETER CURRENT ADJUST to maximum counterclockwise position.

b. Set GAIN controls to maximum counterclockwise position.

c. Set CRYSTAL-BOLO. selector switch to the CRYSTAL position.

d. Energize the equipment by setting the ON-OFF toggle switch to the ON position.

e. Allow the equipment to warm up for 5 minutes.

f. Set CRYSTAL-BOLO. selector switch to the BOLO. position, unless a crystal square-law detector is connected to the input.

g. Without rf power adjust BOLOMETER CURRENT ADJUST for proper bias current as indicated on the BOLOMETER CURRENT meter and required for the specific barretter (usually 4.5 or 8.75 MADC, consult manufacturer's data). The meter will show an indication only if a bolometer is connected to the INPUT of the preamplifier.

CAUTION

Exercise care in adjusting the bolometer bias current to the proper value for the particular bolometer being used. Improper bias adjustment may cause the barretter to burn out. Excessive rf power also may cause the barretter to burn out.

The instrument is now ready for use.

SECTION II

THEORY OF OPERATION

2.1 CIRCUIT OPERATION

(See Figure 1.3.)

The INPUT jack of the Bolometer Preamplifier is connected to the primary of input transformer T-1. Transformer T-1 is a step-up transformer and provides an impedance transformation between the bolometer element and the control grid of the first amplifier tube. The input transformer, which is tuned to 1000 cps, and the feedback circuit provide a resistive input impedance at 1000 cps of approximately 30,000 ohms, which is the load impedance range for video crystals. The primary of T-1 presents essentially an open circuit to the barretter. This avoids any voltage transfer errors. The transformer is designed with an effective magnetic shield to keep noise pickup at a low level. In addition to being connected to the primary of input transformer T-1, the INPUT jack is connected to the bolometer bias circuit. The bias circuit is well-filtered to prevent power supply ripple or other variations from appearing on the signal. The bias circuit allows the operator to connect or disconnect the barretter without danger of burnout due to transient current surges. CRYSTAL-BOLO. selector switch S-1 is provided so that the bias supply may be disconnected from the Bolometer Preamplifier input if the use of crystals is desired. BOLOMETER CURRENT meter MA-1 and BOLOMETER CURRENT ADJUST P-2 provide a convenient means for readily monitoring and setting the bolometer bias current level.

The amplifier consists of tubes V-1 and V-2. The coarse and fine GAIN controls are located between the two halves of amplifier V-2 and after the feedback point so that a change in gain does not affect the amplifier bandwidth.

To make the equipment useful at low rf power levels, internal noise is kept to a minimum. The amplitude of thermal noise is given by the following formula:

$$e_n = \sqrt{4kTRB}$$

where:

e_n is amplitude of thermal noise in volts rms.

k is Boltzmann's constant (1.374×10^{-23}).

T is absolute temperature in degrees K.

R is effective circuit resistance in ohms.

B. is bandwidth in cps.

From the formula it can be seen that the noise voltage can be reduced by decreasing the bandwidth. Therefore the Bolometer Preamplifier has been designed with a very narrow bandwidth (less than 35 cps). This narrow bandwidth is produced by the twin-T filter in the feedback circuit. The filter is tuned to a center frequency of 1000 cps. At frequencies outside the pass band, a large amount of negative feedback is applied to the control grid of an amplifier V-1 through the secondary winding of input transformer T-1; at resonance, the feedback is greatly reduced which provides a sharp peak in the amplifier output voltage at that frequency.

2.2 PRINCIPLES OF RF INSERTION LOSS MEASUREMENTS

The use of the audio substitution method of measurement of an rf insertion loss is based on the assumption that the application of a modulated rf signal to a biased bolometer develops an af voltage that is proportional to the rf power applied. This af voltage is then fed into an amplifier or an af voltmeter. It is therefore possible to measure rf power ratios at the bolometer input by measuring af voltage ratios at the bolometer output. Measurements can be accomplished over a limited range using an accurately calibrated voltmeter to read the audio level. An N db change in audio level will correspond to an N/2 db change in rf level. If a calibrated audio attenuator is used in the substitution arrangement so that the indicator is used only as an index, a high degree of accuracy may be obtained with little operator skill. Power ratio measurements (Figure 2.1) are most easily made

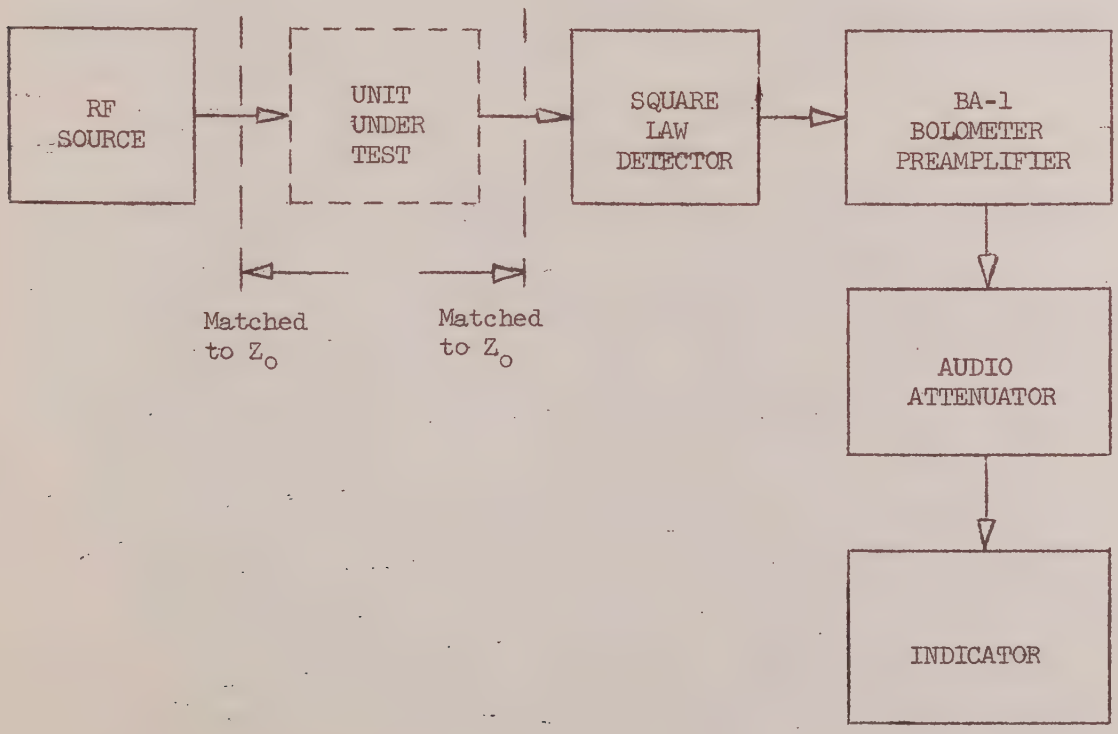


Figure 2.1. Block Diagram for Typical RF Insertion Loss Measurement

with the rf source 100-percent square-wave modulated at 1000 cps. A square-law device is used as a video detector. The demodulated af output voltage of the detector is amplified in a 1000-cps amplifier to produce a usable signal level for an indicator. The unknown insertion loss of the unit under test can be ascertained by measuring the change in the audio level produced when the unit under test is inserted in the line. If the detector is a perfect square-law device, its audio output voltage is proportional to the rf input power. Since audio voltage ratios can be measured with a high degree of accuracy, the accuracy of the measurement system depends mostly on the deviation of the detection device from square law. However, the square-law device must be capable of following the rf power changes sufficiently fast in order to obtain a usable af output signal. The selection of square-law detectors must be made on the basis of:

Required dynamic operating range
Available rf power
Required linearity or accuracy

The minimum usable signal level is determined by the noise generated in the detector and the associated equipment. The equivalent noise resistance of a video crystal is approximately 15,000 ohms while that of a barretter is slightly higher than its dc resistance of 200 ohms. A 200-ohm barretter operating at an elevated temperature, due to the dc bias current, has an equivalent noise resistance of approximately 300 ohms. The noise generated in the equipment is kept to a minimum by maintaining a narrow bandwidth as discussed earlier. The presence of noise results in an increase in the average output signal level and fluctuations in the output meter indications. These two undesirable effects are satisfactorily overcome by maintaining a minimum signal to noise ratio of 8:1 (4)*.

2.3 BARRETTERS AS SQUARE-LAW DETECTORS

A barretter consists of a short length of very fine platinum wire. In use it is supplied with a bias current such that for most barretters the dc resistance is approximately 200 ohms. The application of an rf signal 100-percent modulated at 1000 cps to the barretter causes its resistance to change at the modulation rate and, if the bias current is supplied from a constant-current source, a 1000 cps voltage is developed across the barretter. This voltage will be proportional to the rf power applied to the barretter over a range limited by noise at the low level end, and deviation of the barretter from its square law characteristic at the high level end. A quantitative analysis of these factors has been made (1, 2, 3, 4)* and the reader is referred to the literature for further information.

The noise at the input of the BA-1C is determined mainly by the amplifier. A typical barretter departs from true square-law behavior by only about 0.01 db (rf) at a 1000 cps output level of 3 millivolts rms if the rf power is 100-percent modulated. Due to this small amount of departure, the error contributed by the barretter to the total measurement error can usually be neglected. Typical barretters require 100-percent 1000 cps square-wave modulated rf powers from 130 to 200-microwatts peak to produce an audio voltage of 3 millivolts at the input of the amplifier. If a 20-db attenuator is used for isolation at the output of the generator, the generator must be capable of supplying 20 milliwatts peak of 100-

* Refer to Bibliography

percent square-wave modulated power at the desired radio frequency.

If at the extreme low level a signal-to-noise ratio of at least 8:1 is required at the amplifier input (4)* the minimum usable signal becomes:

$$8 \times 30 \times 10^{-9} = 0.24 \times 10^{-6} \text{ volts}$$

Since a maximum signal of 3×10^{-3} volts can be handled in the input of the BA-1C without excessive departure from linearity, an extreme range of 41 decibels at radio frequencies can be covered using the BA-1C. Audio Level Indicator Model IN-1 manufactured by Weinschel Engineering is recommended for use in this application as described in Application Note No. 1 since it has a long indicator time constant available which enables accurate measurements to be made in the presence of noise (4)*. However, an audio range of 3×10^{-3} volts to 3×10^{-6} volts (30 db rf) is preferred for simple laboratory measurements.

2.4 VIDEO CRYSTAL DIODES AS SQUARE-LAW DETECTORS

A crystal diode exhibits a square-law behavior over a certain range of input powers and can therefore be used in place of a barretter in some applications. A typical video crystal has an equivalent noise resistance of 15,000 ohms as compared to a barretter noise resistance of about 300 ohms. This corresponds to a noise voltage of approximately 90×10^{-9} volts calculated by using the formula in paragraph 2.1 with a bandwidth of 30 cps and an absolute temperature of 300°K (80.6°F). Again assuming at the extreme low level an 8:1 signal-to-noise ratio, the minimum usable signal is found to be:

$$8 \times 90 \times 10^{-9} = 0.72 \times 10^{-6} \text{ volts}$$

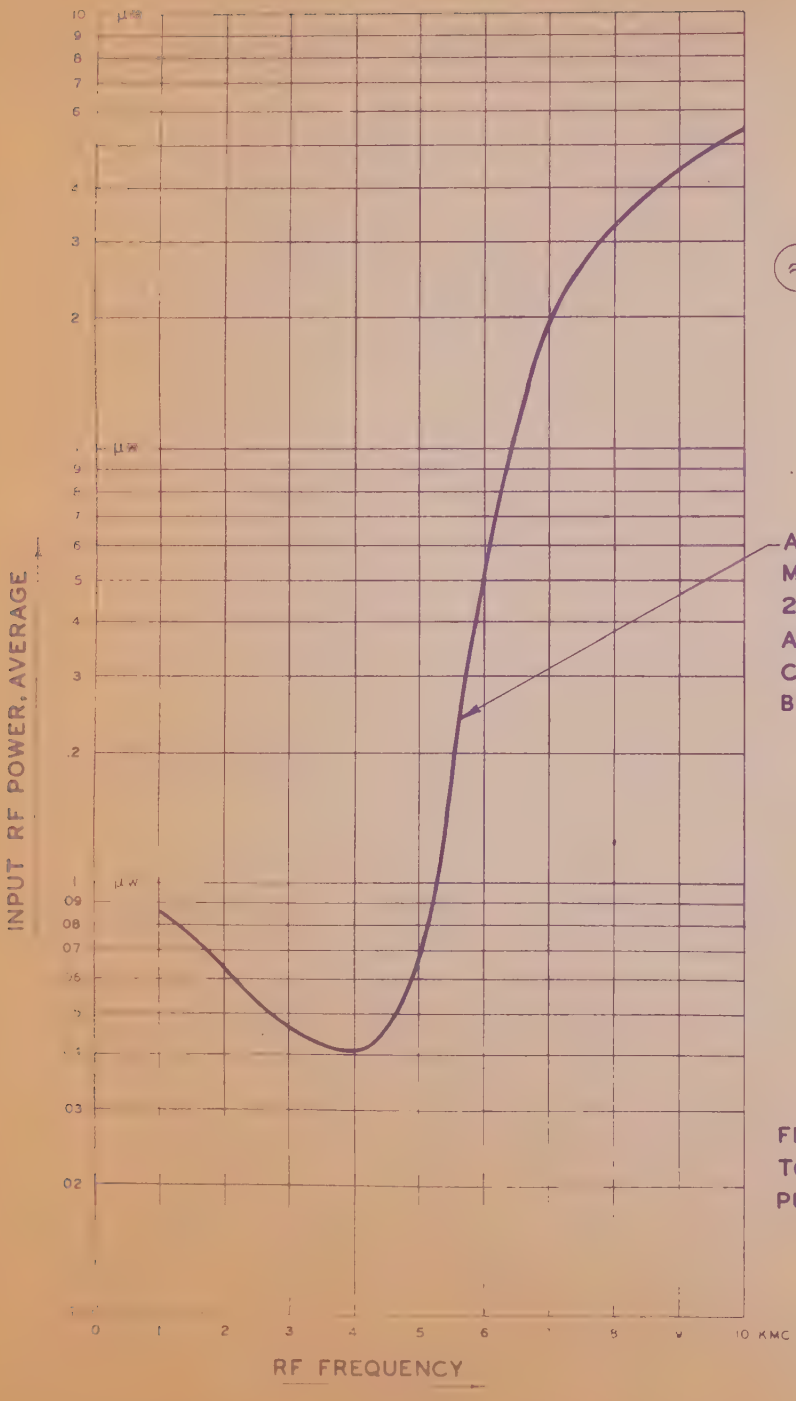
The maximum range of measurement thus becomes:

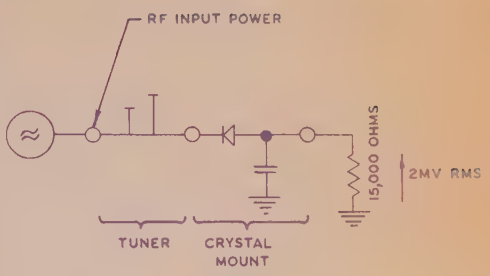
$$\frac{3 \times 10^{-3}}{0.72 \times 10^{-6}} = 4 \times 10^{3}$$

or 36 db, which is less than the maximum range available with a barretter under similar conditions.

The crystal detector has the advantage, however, of requiring less rf power to produce a given detected output voltage. Figure 2.2 shows the average rf input power required to produce an audio voltage of 2×10^{-3} volts rms across a load of 15,000 ohms. This is plotted from data taken on a 1N32 crystal in a coaxial mount

* Refer to Bibliography





AVERAGE RF INPUT POWER (100% MODULATED) NECESSARY TO PRODUCE 2mV RMS AUDIO OUTPUT VOLTAGE ACROSS 15,000 Ω LOAD FOR IN32 CRYSTAL AND MOUNT-TUNER COMBINATION.

FIG. 2.2. RF POWER VS. RF FREQUENCY TO PRODUCE CONSTANT AUDIO OUTPUT VOLTAGE.

preceded by a double-stub tuner. The use of waveguide mounts at the higher frequencies improves the sensitivity. An rf power of one microwatt average will produce the maximum usable signal over most of the frequency range shown. If a 20-db attenuator is used for isolation at the output of the generator, an rf power of only 0.1 milliwatt average is required to make a measurement of 36 db. For further information, refer to reference (4) in the Bibliography. It is much more difficult to match a crystal to the characteristic impedance of the transmission line than a barretter. The frequency stability of the rf source must be higher for such a frequency sensitive match. An accidental overload or mechanical shock may change the square-law characteristics of a crystal. For accurate measurements this characteristic should be verified by measuring the rf insertion loss of a known attenuator. A barretter does not lose its square-law characteristic. Either it burns out due to overload or it operates satisfactorily.

SECTION III

MEASUREMENT PROCEDURE

3.1 ASSOCIATED EQUIPMENT REQUIREMENTS

Bolometer Preamplifier Model BA-1C is used in both the Single Channel and Dual Channel Insertion Loss Test Sets. In either application, additional equipment is required; the associated equipment is shown in Figure 3.1 and Figure 3.2.

Since the Bolometer Preamplifier is tuned to 1000 cps and has a fairly narrow bandwidth, it is necessary that the rf source be 100-percent square-wave modulated at a frequency of 1000 cps. Modulating frequency stability, as well as amplitude stability, is important since a variation in the rf source output during measurement will cause an error. Self-contained Modulated RF Source Models MS-1, MS-2 and MS-3, manufactured by Weinschel Engineering, meet these rf source requirements and cover the frequency range of 50 to 2000 mc. Plug-in RF Source Models MS-8 through MS-11 and MS-13, MS-16 and MS-17, used with Power Supply - Modulator Model MO-3 also meet the rf source requirements and cover the extended frequency range of 50 to 21,000 mc. In addition, Modulator Model MO-1 is available for use with rf sources that do not have internal 1000-cps square-wave modulation with sufficient stability. The MS-1, MS-2 and MS-3 sources are provided with an optional amplitude stabilization. Stabilization is accomplished by sampling the incident power in an external directional coupler in the output line and feeding this back to control the oscillator power supply output. With an rf output capacity of 20 milliwatts into a 50-ohm load, 20 db of isolation is normally used following the rf generator. Additional isolation may be used, if sufficient power is available, but in no case should less than 20 db of isolation be used.

3.2 PROCEDURE FOR MAKING SINGLE CHANNEL RF INSERTION LOSS MEASUREMENTS

(See Application Note No. 1 in Appendix.)

The Bolometer Preamplifier is connected as shown in Figure 3.1 to measure an unknown rf insertion loss. The range of measurement depends on the noise generated in the bolometer and the preamplifier input circuit at low rf levels and upon the linearity of the complete test set at high rf levels. The Single Channel Insertion Loss Test Set can be used to measure radio-frequency power ratios up to 40 db. A 100-percent, 1000-cps square-wave modulated rf source is required which is stable enough in frequency and output power to make accurate measurements possible. The rf power output should be at least 20 milliwatts. A 20-db pad is inserted following the rf source to prevent reactions on the source by the insertion of the unit under test into the line. A matching device, such as a double-stub tuner, is added following the pad so that the insertion loss of the unit under test may be measured between points having equal impedances. A slotted line and VSWR indicator are included since it is usually required that VSWR measurements be taken at the same time as the insertion loss measurement. A second double-stub tuner is added between

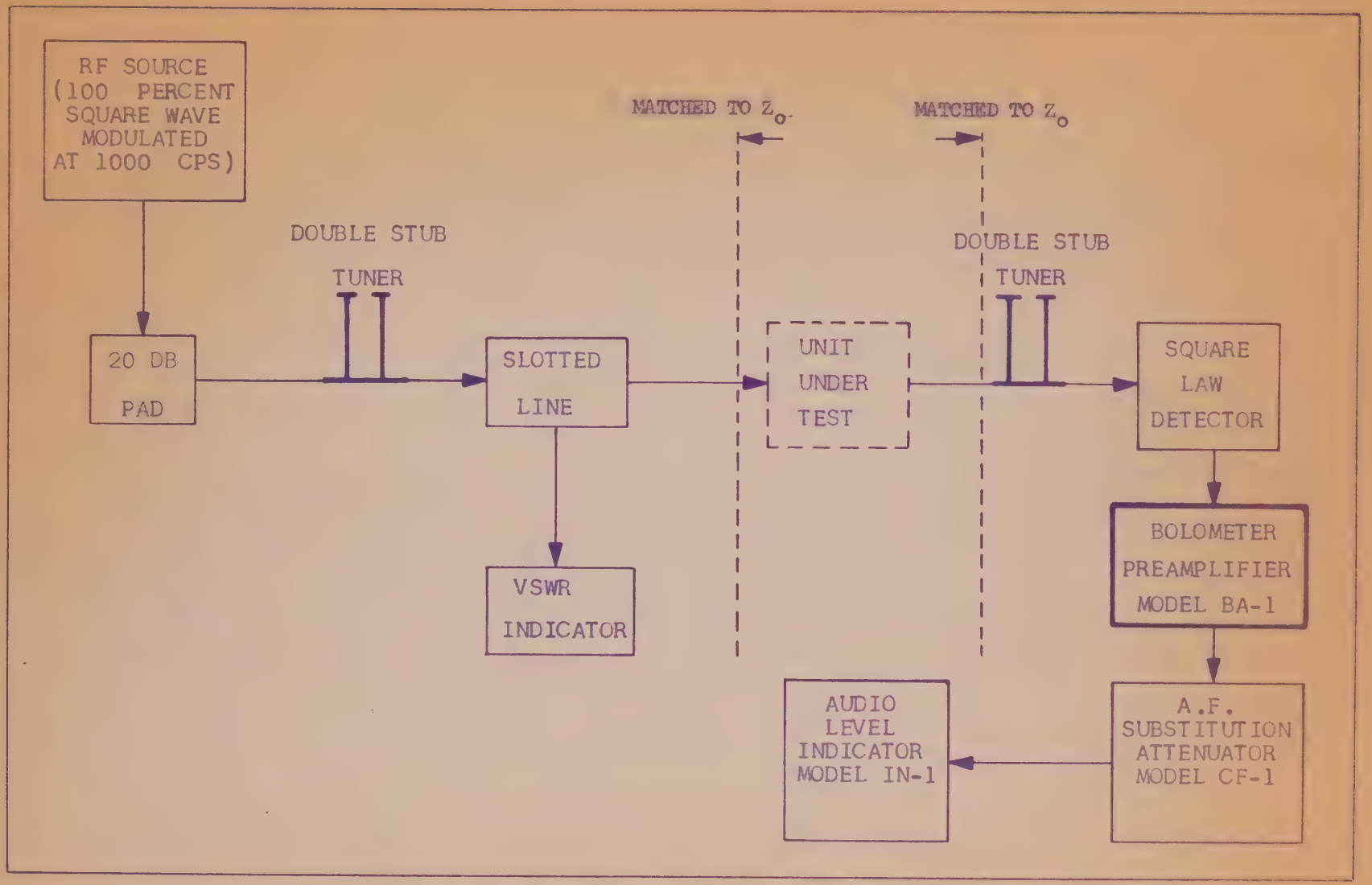


Figure 3.1. Single Channel Insertion Loss Test Set, Block Diagram.

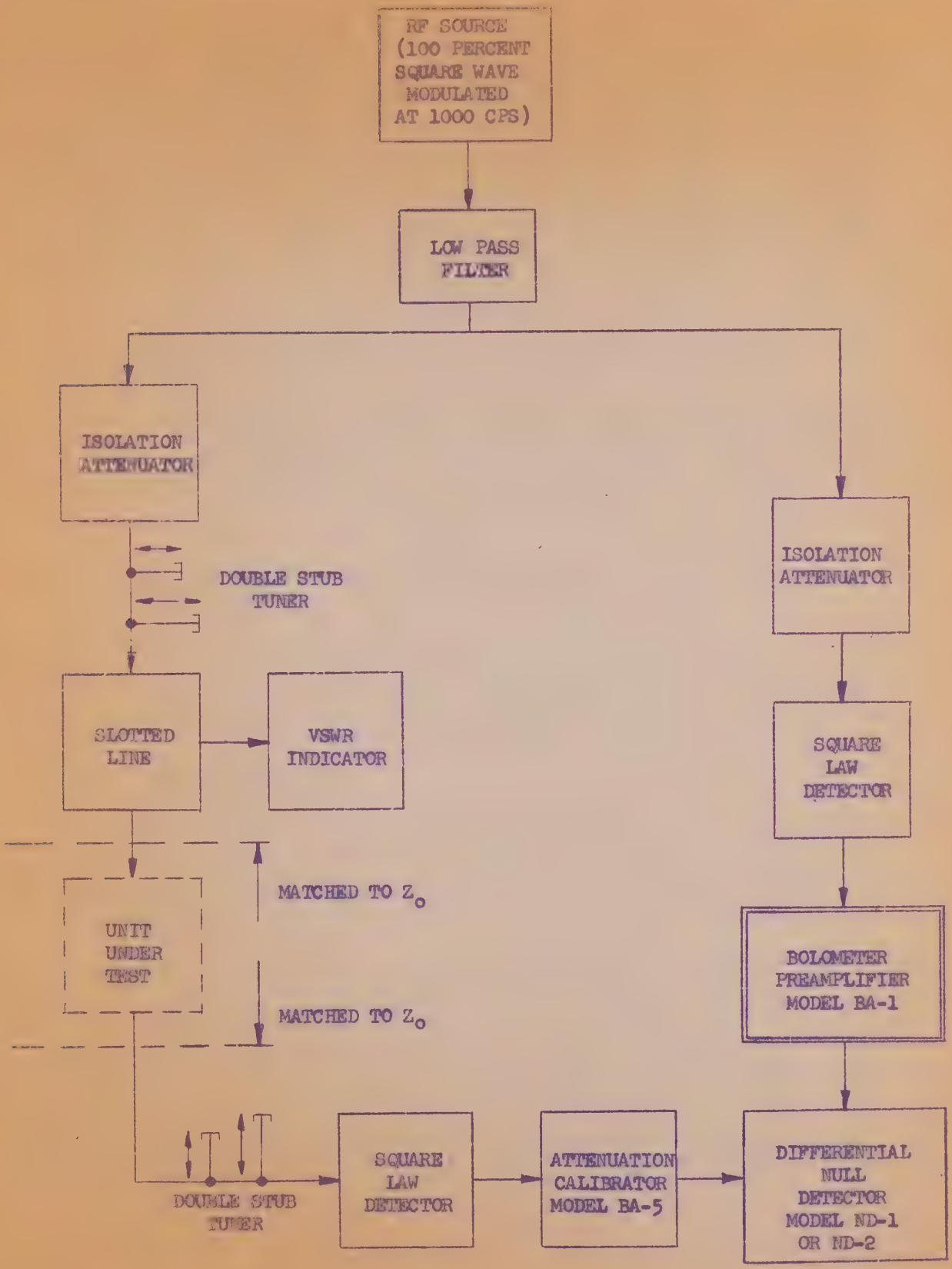


Figure 3.2. Dual Channel Insertion Loss Test Set, Block Diagram

the unit under test and the square-law detector to insure a low VSWR when looking into the detector. A barretter-type bolometer, preferably, or a crystal may be used as the detector to demodulate the signal. If a barretter is used, it is necessary to provide proper bias current and avoid exceeding its maximum power rating. If a crystal is used, one should be selected which will provide square-law detection under the prevailing conditions. The bias current must be disconnected by setting the CRYSTAL-BOLO. selector switch to the CRYSTAL position. To make an rf insertion loss measurement, set the attenuation controls on AF Substitution Attenuator Model CF-1 to a setting that is several db higher than the expected attenuation of the unit to be tested.

NOTE

Refer to AF Substitution Attenuator Model CF-1 Instruction Manual (IM #4) for operating instructions.

With the unit under test out of the line, adjust the Bolometer Preamplifier GAIN controls to produce a convenient meter reading on Audio Level Indicator Model IN-1. It is advisable to make the reading correspond to one of the fine division lines on the indicator so that it can be reset easily and accurately.

NOTE

Refer to Audio Level Indicator Model IN-1 Instruction Manual (IM #7) for operating instructions.

The unit under test is then inserted into the line, as shown in Figure 3.1, and audio attenuation is then removed from the circuit by means of the AF Substitution Attenuator until the Audio Level Indicator returns to its original reading. The db difference between the two settings of the attenuation controls on the AF Substitution Attenuator is then equal to the rf insertion loss of the unit under test.

3.3 EXTENSION OF MEASUREMENT RANGE

When using the Single Channel Insertion Loss Test Set, the maximum single step direct measurement range using barretters is limited by noise and non-linearity to approximately 40 db. If an insertion loss greater than 40 db is to be measured, a partial rf substitution method may be used provided sufficient power output from the rf source is available.

A 20- or 30-db pad is first calibrated following the procedure previously explained. RF power is then increased until the conditions given in paragraph 3.2 can be obtained with the calibrated pad in the line and the AF Substitution Attenuator set several db higher than the difference between the unit under test and the calibrated pad. The unit under test is then substituted for the calibrated pad, and the AF Substitution Attenuator reset to return the meter to its reference reading. The unknown attenuation is equal to the db difference between the two settings of the attenuation controls of the AF Substitution Attenuator plus the value of the calibrated pad. This method may be used to measure insertion losses up to 60 db if 200 milliwatts of power is available from the rf source at the characteristic impedance Z_o.

3.4 PROCEDURE FOR MAKING DUAL CHANNEL RF INSERTION LOSS MEASUREMENTS

(See Application Note No. 4 in Appendix.)

To increase the resolution and accuracy, in spite of small variations in rf level particularly when measuring low-level insertion losses, the Dual Channel Insertion Loss Test Set is advantageous. In this test set, the block diagram of which is shown in Figure 3.2, a null detector is used to compare the difference between two channels. One channel has only fixed component values and is used as the reference channel. The other channel contains the unit under test and is used as the measurement channel. The dual channel method permits a maximum measurement to 20 db using the ND-1 and to 30 db using the ND-2 which can be repeated with a precision of 0.01 db per 10 db (rf) of measurement range. The test set has an absolute accuracy of 0.02 db/10 db when used with recommended accessories (Figure 3.2). Small variations in the rf signal generator output level are not a source of error.

To measure the unknown rf insertion loss, assemble the equipment as shown in Figure 3.2. It is essential to employ the proper rf equipment for the measuring frequency used. It is usually advisable to operate Bolometer Preamplifier Model BA-1C and Attenuation Calibrator Model BA-5 from a regulated line voltage, such as a Sorensen AC Voltage Regulator. When a regulator is used, it should be removed several feet from all equipment so that its magnetic field does not cause any disturbance. With the unknown attenuation out of the measurement channel, tune the RF Source, modulated 100-percent with a 1-kcs square wave, to the desired frequency. The input signal levels to the Bolometer Preamplifier and Attenuation Calibrator should be adjusted, if necessary, to 2 millivolts or under. By means of the tuning stubs and a slotted line, adjust the combination of bolometer mount and double-stub tuner for minimum VSWR. This establishes a load impedance matched to Z_o for the unit under test. Set a greater attenuation on the attenuator controls of the Attenuation Calibrator than the expected value of the unknown loss. For example, if the unknown loss is expected to be 10 db, insert at least 12 db in the Attenuation Calibrator so that the equipment has sufficient range to measure accurately. The 1000-cps modulation frequency must be stable to better than .01 percent. The single channel measurement does not require such a stability.

3.5

NOTE

Refer to Attenuation Calibrator Model BA-5 Instruction Manual (IM #2) for operating instructions.

With the attenuation set, adjust the COARSE and FINE GAIN controls of the Attenuation Calibrator to produce a signal approximately of 0.3 volt across the measurement INPUT of Differential Null Detector Model ND-1 (which corresponds to a reading of about 7 db on the Attenuation Calibrator meter). Adjust the GAIN controls on the Bolometer Preamplifier to produce a signal of approximately 0.6 volt across the measurement INPUT of the Differential Null Detector. INPUT NO. 1 requires a signal that has about twice the amplitude of the signal applied to INPUT NO. 2, since the internal reference channel circuits of the Differential Null Detector have a gain of

approximately 0.5. (In the ND-2, both inputs have equal sensitivity). In order to obtain a null on the meter of the Differential Null Detector, both the amplitude and phase of the signal must be adjusted. Since the input voltages to both inputs were set at 0.6 and 0.3 volt respectively, the amplitudes are nearly correct. Therefore the next step is to improve the phase balance. On the Differential Null Detector, operate 0 degree - 180 degree toggle switch first to the 0 degree position and then the 180 degree position.

3.6

NOTE

Refer to Differential Null Detector Model ND-1 or ND-2 Instruction Manual (IM #3) for operating instructions.

Set the toggle switch to the position producing the lower UNBALANCE meter reading. Then try all 10 positions of the COARSE PHASE SHIFT CONTROL on the Differential Null Detector and leave the control on the position producing the lowest meter reading. If this happens to be the first or last position of the control, operate the 0 degree - 180 degree toggle switch to its other position and see if there is a new position of the COARSE PHASE SHIFT CONTROL producing a lower meter reading. Reduce the UNBALANCE meter reading by carefully adjusting the FINE GAIN control on the Attenuation Calibrator. Then reduce the meter reading still further by means of the MEDIUM PHASE SHIFT CONTROL on the Differential Null Detector and the FINE GAIN control on the Attenuation Calibrator. (A reading below 25 on the UNBALANCE meter is usually achieved within 30 seconds). Continue to carefully adjust the MEDIUM and FINE PHASE SHIFT CONTROL and FINE GAIN control until a null indication is obtained on the UNBALANCE meter. Insert the unit under test in the line and readjust the attenuator controls on the Attenuation Calibrator for zero deflection of the UNBALANCE meter.

NOTE

Measurements above 10 db may also require slight readjustment of the PHASE SHIFT CONTROLS on the Differential Null Detector.

The attenuation removed from the attenuator control settings on the Attenuation Calibrator is the rf insertion loss in db introduced by the unit under test.

SECTION IV

MAINTENANCE AND CALIBRATION PROCEDURES

4.1 GENERAL

Bolometer Preamplifier Model BA-1C has been designed to require a minimum of maintenance; however, as with all electron tube operated equipment, normal preventive maintenance is required. Should trouble develop and service become necessary, the normal procedures for corrective maintenance are applicable.

4.2 TUBE TESTING AND REPLACEMENT

It is recommended that a mutual conductance type tube checker be used to determine the condition of the electron tubes. In general, no special precautions need be taken when selecting replacement tubes. On rare occasions, selected tubes for the replacement of V-1 (6AU6) or V-2 (5814) may be necessary if the noise level is high or if the amplifier has a microphonic tendency.

4.3 REPLACEMENT OF COMPONENTS

Resistance, capacitance, and voltage values are shown on the schematic diagram, Figure 1.3. The voltage measurements were made with a 20,000 ohms-per-volt meter. Standard resistance and capacity checks will isolate faults. Component parts in the twin-T filter network, as indicated in the parts list, are critical and have selected values. If this filter network is disturbed or changed in any way, the performance of the equipment will be impaired and inaccurate results will be obtained. Should trouble be localized to the twin-T filter network, it is recommended that the Bolometer Preamplifier be returned to Weinschel Engineering, Kensington, Maryland, for adjustment.

4.4 PERIODIC MAINTENANCE CHECKS

Maintenance checks and calibration should be performed on a quarterly basis under normal operating conditions to insure the accuracy and reliability of the equipment. The equipment should be warmed up for at least one hour before starting the following check procedures. A complete list of test equipment required will be found in Table 4.1.

4.5 CENTER FREQUENCY AND BANDWIDTH CHECK PROCEDURE

A measurement of the center frequency and bandwidth of the Bolometer Preamplifier can be made by setting up the equipment as shown in Figure 4.1. Adjust the audio oscillator frequency to 1000 cps and the signal amplitude to provide a 3 mv input to the Bolometer Preamplifier. Switch the audio vacuum-tube voltmeter to a higher range, at least 30 volts, and connect it to the Bolometer Preamplifier OUTPUT connector. Adjust the oscillator frequency for a maximum meter deflection on the vacuum-tube voltmeter. The frequency as read on the universal counter should be 1000 ± 2 cps which is the center frequency of the equipment. Decrease

the frequency until the output of the Bolometer Preamplifier drops off 3 db as noted on the vacuum-tube voltmeter. Note the frequency at this point. Now increase the frequency until the output of the Bolometer Preamplifier increases to maximum and then drops off 3 db. Note this frequency. The difference in the two frequencies noted, between 3 db points, should not be less than 25 cps nor more than 35 cps. This is the bandwidth of the equipment.

4.6 GAIN CHECK PROCEDURE

The gain of the Bolometer Preamplifier may be measured using the same equipment set-up as for the bandwidth and center frequency measurements. Adjust the oscillator frequency for 1000 cps and the signal amplitude to provide a 3 mv input to the Bolometer Preamplifier. Set the coarse and fine GAIN controls on the Bolometer Preamplifier to their maximum clockwise position. Switch the vacuum-tube voltmeter to a higher range, at least 30 volts, and connect it to the Bolometer Preamplifier's OUTPUT connector. The vacuum-tube voltmeter should read at least 30 volts which indicates a gain of 10,000.

4.7 NOISE CHECK PROCEDURE

After performing the gain check, set the gain of the Bolometer Preamplifier to exactly 10,000 and remove the signal from the INPUT connector. Connect a shielded 200-ohm wirewound resistor to the INPUT connector of the Bolometer Preamplifier. Adjust the BOLOMETER CURRENT ADJUST for a 9.0 milliampere BOLOMETER CURRENT meter reading. The reading on the vacuum-tube voltmeter, connected to the OUTPUT connector, should not exceed 0.30 millivolts. Turn the bias control back to zero.

4.8 LINEARITY CHECK PROCEDURE

With the gain of the BA-1C set to exactly 10,000 (paragraph 4.6), connect the equipment as shown in Figure 4.2. Place the CATHODE FOLLOWER - 2000 OHMS switch of the CF-1 to the CATHODE FOLLOWER position, and adjust the frequency of the audio oscillator to 1000 ± 1 cps. Insert 20 db (af) of attenuation into each audio attenuator. Adjust the output voltage of the audio oscillator until the input voltage to the BA-1C is 3 mv rms. The output voltage of the audio oscillator will then be about 0.3 volts rms. Set in 30.05 db (rf) on the CF-1 using two 0-10 db rf lever switches, the 0-10 rf db selector switch and the .01 db vernier control.

NOTE

> The CF-1 is calibrated in rf db; therefore 1 db (rf) on the CF-1 corresponds to 2 db (af) on the audio attenuators.

Set the range selector switch of VTVM No. 2 to the 50 millivolts position. The meter should indicate 15 ± 5 mv. Vary the .01 db vernier control of the CF-1 until VTVM No. 2 indicates on one of the fine divisions. (For reasons which will

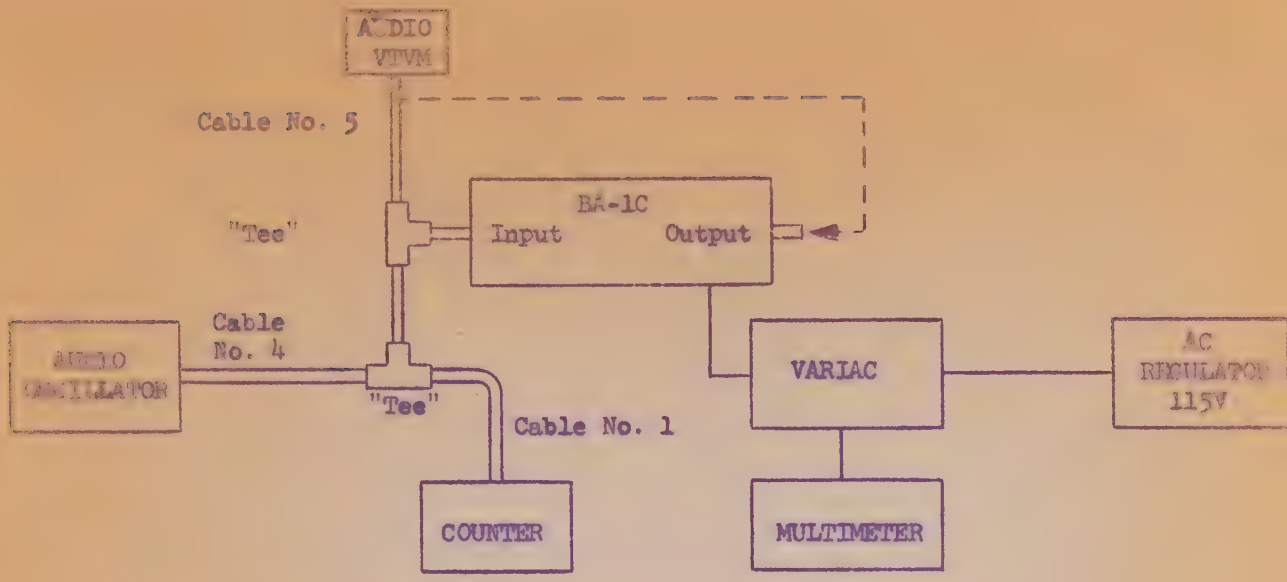


Figure 4.1. Test Equipment Set-Up for Center Frequency and Bandwidth Determination

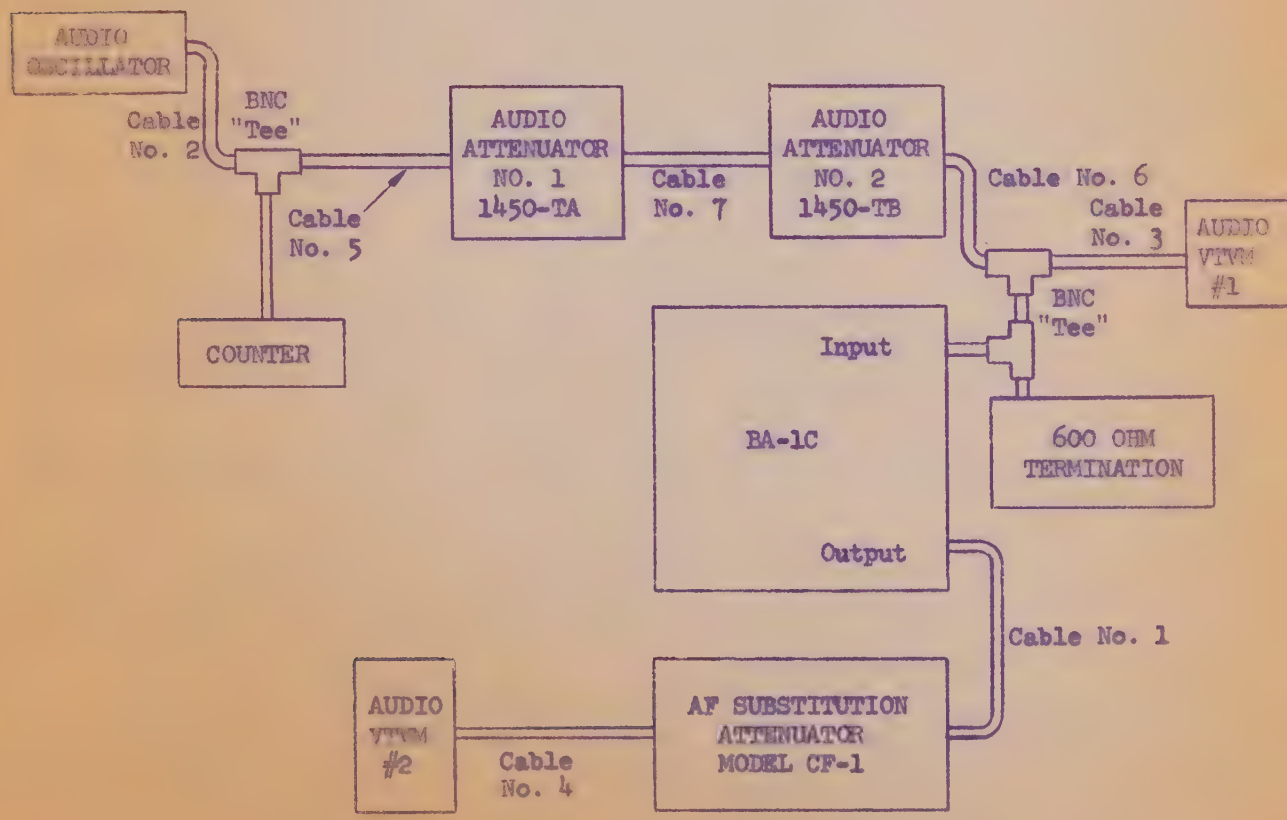


Figure 4.2. Linearity, Test Equipment Set-Up

be apparent later, the vernier should indicate between the .04 and .06 graduations).

NOTE

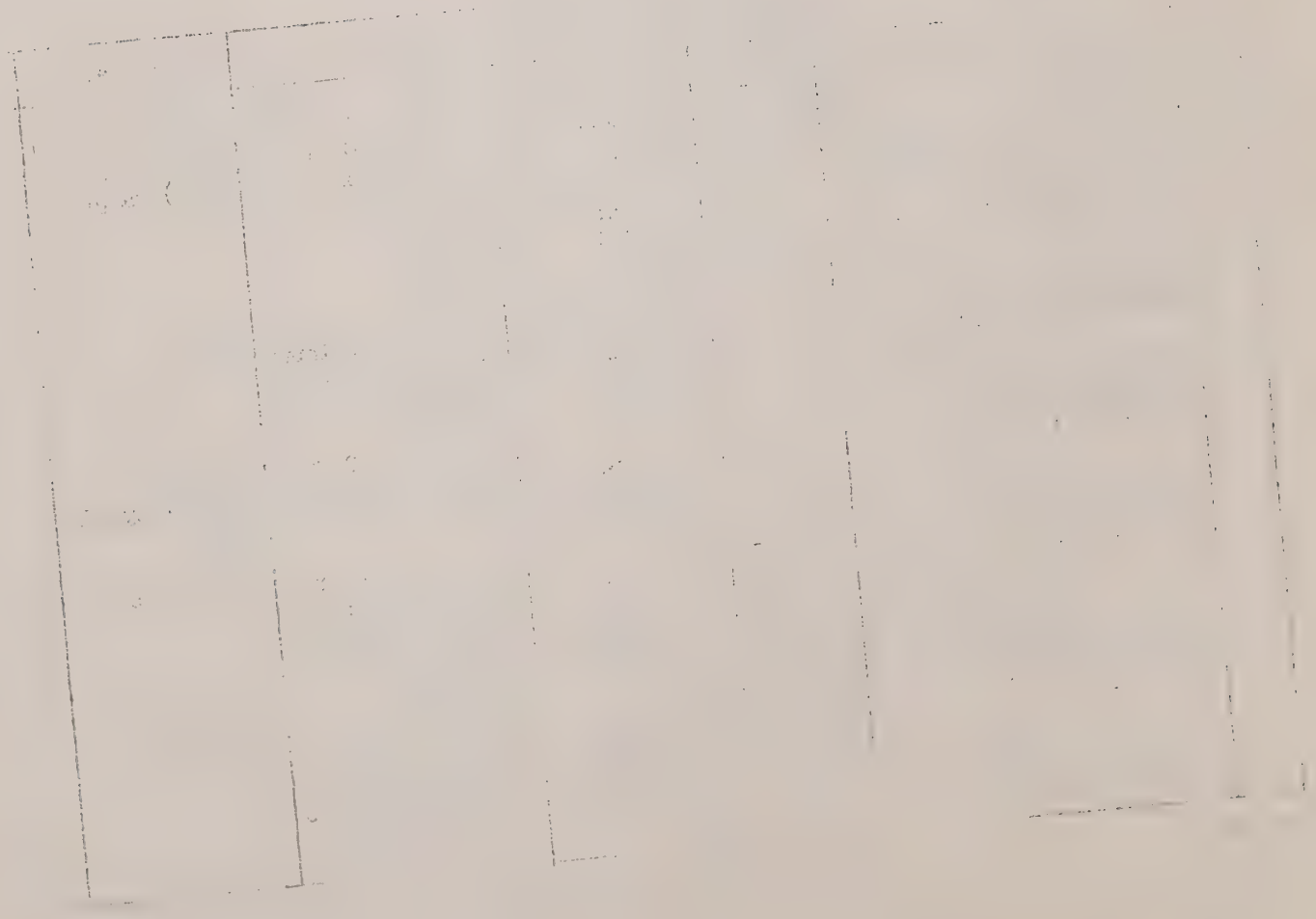
These are the reference positions of VTVM No. 2 and the .01 db vernier control.

Add 20 db (af) of attenuation to audio attenuator No. 1 in 2 db (af) steps, and simultaneously decrease the attenuation of the CF-1 in 1 db (rf) steps. VTVM No. 2 should return to its reference indication after each step. If necessary adjust the .01 db vernier control of the CF-1 to obtain the meter reference indication.

Increase the attenuation of audio attenuator No. 2 by 40 db (af) in 2 db (af) steps, and simultaneously remove attenuation from the CF-1 in 1 db (rf) steps. VTVM No. 2 should return to its reference indication after each step. If necessary adjust the .01 db vernier control of the CF-1 to obtain the meter reference indication. The indication of the .01 db vernier control must not vary more than 0.05 db (rf) over the complete range covered (60 db af) or 0.01 db (rf) over the second part of the range (40 db af). During the entire procedure make certain the frequency and the output level of the audio oscillator remain at the values set at the beginning of the test. A change in either will affect the results obtained and the entire linearity check will have to be repeated.

TABLE 4.1
Test Equipment Required

Qty	Nomenclature	Model No.	Application	Range	Accuracy
1	AF Substitution Attenuator (Weinschel Engineering Co.)	CF-1	Variable Attenuator	60 db (af) range, 100 to 10,000 cps	±0.04 db (af) for 60 db (af) range
1	Audio Oscillator (Hewlett-Packard Co.)	200CD	Variable Oscillator	5 cps to 600 kc	
2	Audio Vacuum Tube Voltmeter (Instrument Electronics Co.)	247	Measurement of ac voltages	0.5 mv to 500 volts rms. Input impedance, 7 megohms	±1%
1	Universal Counter (Berkeley)	5510	Electronic counting	DC to 1,000,000 cps	Crystal stability ±1 count
1	Audio Attenuator (General Radio)	1450-TA	Variable Attenuator	0 to 100 db in 10 db steps; 0 to 10 db in 1 db steps	±0.005 db
1	Audio Attenuator (General Radio)	1450-TB	Variable Attenuator	0 to 100 db in 10 db steps; 0 to 10 db in 1 db steps; 0 to 1 db in 0.1 db steps	±0.005 db



4.9 ACCESSORY CABLES REQUIRED

The coaxial cables and the types of coaxial connectors for each cable employed for equipment connections in the various maintenance checks are listed in Table 4.2.

TABLE 4.2
List of Coaxial Cable Assemblies Required

Cable No.	Cable Type	Connectors	Length
1	RG-58A/U	UG-88/U (two)	2 feet
2	RG-58A/U	GR type 274 NK (one), UG-88/U (one)	3 feet
3	RG-58A/U	GR type 274 NK (one), UG-88/U (one)	3 feet
4	RG-58A/U	GR type 274 NK (one), UG-88/U (one)	2 feet
5	RG-58A/U	GR type 274 NK (one), UG-88/U (one)	3 feet
6	RG-58A/U	GR type 274 NK (one), UG-88/U (one)	3 feet
7	RG-58A/U	GR type 274 NK (two)	1 foot

Note: Three type UG-274/U connectors are also required.

SECTION V

PARTS BREAKDOWN

5.1 INTRODUCTION

Designation symbols have been assigned to identify all maintenance components related to the Bolometer Preamplifier Model BA-1C. The designation symbols, comprised of a letter-number combination, are marked on the equipment adjacent to the component they identify; the same symbol also appears on the schematic diagram and parts lists. The letter of the designation symbol indicates the type of part or related group, such as a capacitor (C), a resistor (R), or an electron tube (V); the number differentiates between parts of the same related group, as R12 or R8.

5.2 MAINTENANCE PARTS LIST

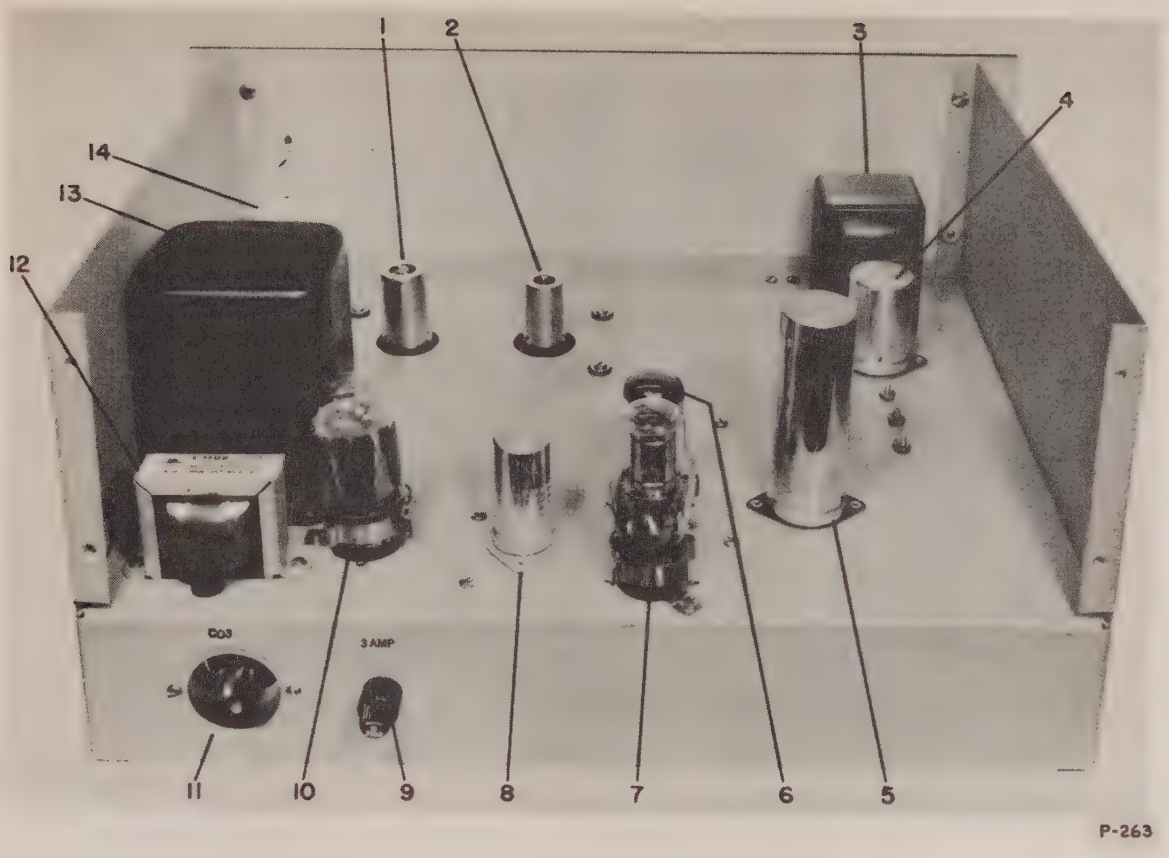
Table 5.1 provides a complete listing of the electronic maintenance components for Bolometer Preamplifier Model BA-1C; to facilitate their identification and ordering, see Figures 5.1 and 5.2. The first column of Table 5.1 lists the designation symbols in alpha-numerical order. The second column gives the Weinschel Engineering part number for ordering the part. The third column describes the part. On identical parts, a complete description is given the first time the part appears on the listing; the description is omitted thereafter. Identical components each have individual designation symbols, as in the case of C6 and C7.

NOTE

The following provides additional information on the parts listed in Table 5.1.

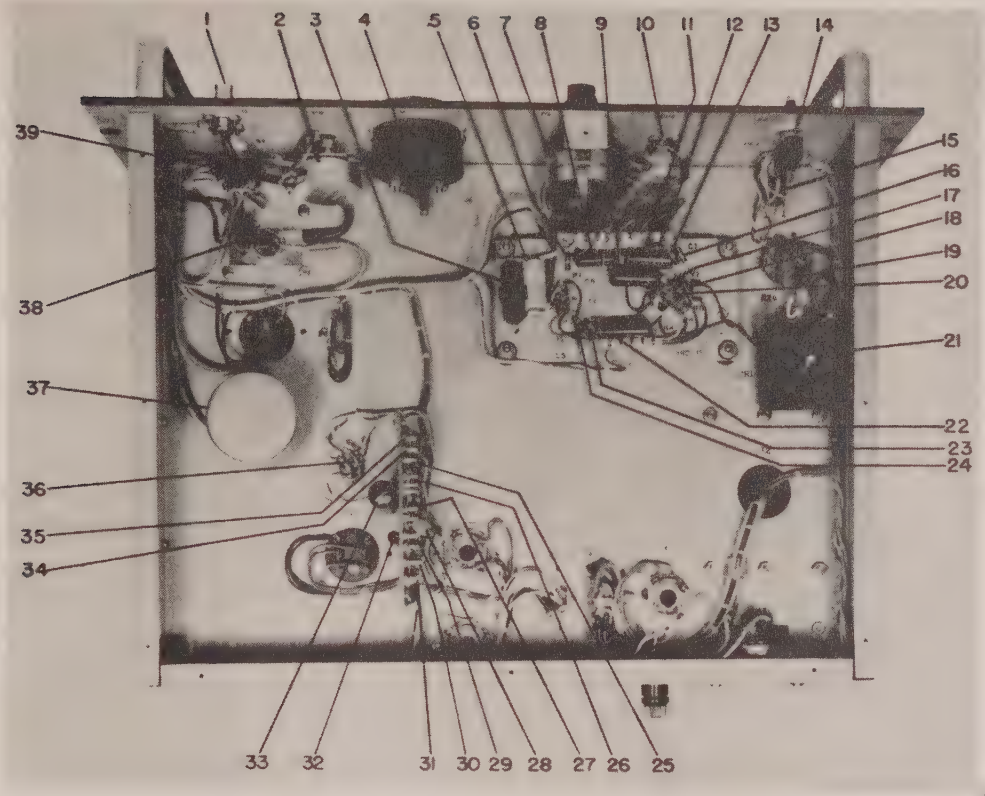
a) Capacitors C-9 through C-12 and resistor R-1 are selected to provide optimum overall operation of the Bolometer Preamplifier.

b) The 3-wire grounding-type adapter and power cord do not have circuit symbol numbers.



1	Tube V-2	8	Capacitor C-15
2	Tube V-1	9	Fuse F-1
3	Transformer T-1	10	Tube V-3
4	Capacitor C-1	11	Connector CO-3
5	Capacitor C-13	12	Choke L-1
6	Tube V-4	13	Transformer T-2
7	Tube V-6	14	Capacitor C-14

Figure 5.1. Top View of Chassis



1 Connector CO-1
2 Potentiometer P-2
3 Capacitor C-4
4 Meter MA-1
5 Capacitor C-3
6 Resistor R-1
7 Potentiometer P-1
8 Capacitor C-7
9 Capacitor C-8
10 Connector CO-2
11 Capacitor C-6
12 Resistor R-5
13 Resistor R-7
14 Switch S-2
15 Lamp Assembly PL-1
16 Resistor R-8
17 Resistor R-4
18 Resistor R-6
19 Resistor R-24
20 Resistor R-9
21 Rectifier CR-1
22 Capacitor C-5
23 Resistor R-3
24 Resistor R-2
25 Resistor R-17
26 Resistor R-18
27 Resistor R-19
28 Capacitor C-19
29 Resistor R-21
30 Resistor R-22
31 Resistor R-23
32 Resistor R-20
33 Capacitor C-18
34 Resistor R-16
35 Resistor R-15
36 Tube V-5
37 Twin Tee Filter
38 Capacitor C-2
39 Switch S-1

Figure 5.2. Bottom View of Chassis

TABLE 5.1
Parts List for Bolometer Preamplifier Model BA-1C

Symbol	Weinschel Part No.	Nomenclature
C-1	32-1	Capacitor - Electrolytic, 2000 µf, 6 v
C-2	34-2-500	Capacitor - Silvered mica, 500 µµf, 300 v
C-3	31-2	Capacitor - Electrolytic, 50 µf, 25 v
C-4	33-2-R1	Capacitor - Molded paper, 0.1 µf, 400 v
C-5		Same as C-4
C-6	33-2-R05	Capacitor - Molded paper, 0.05 µf, 400 v
C-7		Same as C-6
C-8	33-2-R01	Capacitor - Molded paper, 0.01 µf, 200 v
C-9		Capacitor - Silvered mica, selected value (minimum value, 0.01 µf)
C-10		Same as C-9
C-11		Same as C-9
C-12		Same as C-9
C-13	32-10	Capacitor - Electrolytic, 3-section, 60/60/80 µf, 350 v
C-14	32-2	Capacitor - Electrolytic, 1000 µf, 15 v
C-15	32-11	Capacitor - Electrolytic, 2-section, 10/10 µf, 450 v
C-16		Not used
C-17		Not used
C-18	33-3-R1	Capacitor - Molded paper, 0.1 µf, 600 v
C-19	33-6-1	Capacitor - Metalized paper, 1 µf, 200 v
CO-1	63-1	Connector - Coaxial, UG-90/U
CO-2	63-14	Connector - Coaxial, UG-928/U
CO-3	62-38	Connector - Motor base, 3-wire grounding type, male
CR-1	14-2	Rectifier - Selenium, bridge type, 20 vdc, 1.4 amp

TABLE 5.1 (Continued)
Parts List for Bolometer Preamplifier Model BA-1C

Symbol	Weinschel Part No.	Nomenclature
F-1	52-1-3	Fuse - 3 amp
L-1	40-40	Choke - Filter, 13 h, 65 ma
MA-1	16-1	Meter - 0 to 10 ma dc
P-1	20-10	Resistor - Variable, wirewound, 2-section 15k/3k ohm, 3 w
P-2	20-5	Resistor - Variable, wirewound, 100 ohm, 4 w
PL-1	51-4, 50-1	Pilot lamp assembly - 6.3 v with No. 47 bulb
R-1		Resistor - Composition, selected value (approx. value 2.2k ohm, 1/2 w)
R-2	25-1-1R2M	Resistor - Composition, 1.2M ohm ±10%, 1/2 w
R-3	25-1-390K	Resistor - Composition, 390k ohm ±10%, 1/2 w
R-4	25-1-10K	Resistor - Composition, 10k ohm ±10%, 1/2 w
R-5	25-1-1200	Resistor - Composition, 1200 ohm ±10%, 1/2 w
R-6	25-1-2R2M	Resistor - Composition, 2.2M ohm ±10%, 1/2 w
R-7	25-1-47K	Resistor - Composition, 47k ohm ±10%, 1/2 w
R-8		Same as R-4
R-9	25-1-100K	Resistor - Composition, 100k ohm ±10%, 1/2 w
R-10	26-2-15915	Resistor - Wirewound, 15.915k ohm ±0.1%, 1/2 w
R-11		Same as R-6
R-12	26-2-7957	Resistor - Wirewound, 7957 ohm ±0.1%, 1/2 w
R-13		Same as R-10
R-14	25-1-1M	Resistor - Composition, 1M ohm ±10%, 1/2 w
R-15	26-6-2000	Resistor - Composition, 2000 ohm ±5%, 5 w

TABLE 5.1 (Continued)
Parts List for Bolometer Preamplifier Model BA-1C

Symbol	Weinschel Part No.	Nomenclature
R-16	26-6-3000	Resistor - Composition, 3000 ohm ±5%, 5 w
R-17	26-6-1000	Resistor - Wirewound, 1000 ohm ±5%, 5 w
R-18	25-1-270K	Resistor - Composition, 270k ohm ±10%, 1/2 w
R-19		Same as R-2
R-20	25-3-10K	Resistor - Composition, 10k ohm ±10%, 2 w
R-21	25-3-4700	Resistor - Composition, 4700 ohm ±10%, 2 w
R-22	25-4-120K	Resistor - Composition, 120k ohm ±1%, 1/2 w
R-23	55-4-68K	Resistor - Composition, 68k ohm ±1%, 1/2 w
R-24	26-17-1	Resistor - Wirewound, 1 ohm ±10%, 2 w
S-1	55-2	Switch - Toggle, 2-circuit
S-2	55-1	Switch - Toggle, SPST
T-1	40-47	Transformer - Input
T-2	40-56	Transformer - Power
V-1	10-2	Tube - Electron, type 6AU6
V-2	10-7	Tube - Electron, type 5814
V-3	10-1	Tube - Electron, type 5V4
V-4	10-107	Tube - Electron, type 6W6
V-5		Same as V-1
V-6	10-19	Tube - Electron, type 0A3/VR-75
	68-4	Adapter - 3-wire to 2-wire grounding type
	68-3	Power cord - 3-wire grounding type

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1. G. U. Sorger and B. O. Weinschel, "Precise Insertion Loss Measurements Using Imperfect Square Law Detectors and Accuracy Limitations Due to Noise", IRE Transactions on Instrumentation. Vol. I-4, October, 1955. (Reprinted as Weinschel Engineering Notes No. 1)

2. B. O. Weinschel, "Insertion Loss Test Sets Using Square Law Detectors", IRE Transactions on Instrumentation, Vol. I-4, October, 1955. (Reprinted as Weinschel Engineering Notes No. 2)

3. G. U. Sorger, "The Thermal Time Constant of a Bolometer", IRE Transactions on Instrumentation, Vol. I-4, October, 1955. (Reprinted as Weinschel Engineering Notes No. 3)

4. G. U. Sorger and B. O. Weinschel, "Comparison of Deviations from Square Law for RF Crystal Diodes and Barretters", IRE Transactions on Instrumentation, Vol. I-8, December, 1959.

5. C. G. Montgomery, Technique of Microwave Measurements (Vol. 11, M.I.T. Radiation Laboratory Series, McGraw-Hill).

APPENDIX

INSERTION LOSS MEASUREMENTS

Weinschel Engineering Application Notes Nos. 1 and 4 are included in this manual to supply additional information on using Bolometer Preamplifier Model BA-1 when conducting single and dual channel insertion loss measurements.

The application notes provide complete information on the interconnection of various test equipment and accessories, the items which should be used for each specific frequency range, and the method of measuring insertion losses.

W A R R A N T Y

Weinschel Engineering warrants each instrument of its manufacture to be free from defects in material and workmanship. Our obligation under this warranty is limited to servicing or adjusting any instrument returned to our factory for that purpose, and to making good at our factory any part or parts thereof (except tubes, fuses, or batteries) which shall, within one year after making delivery to the original purchaser, be returned to us with transportation charges prepaid, and which on our examination shall disclose to our satisfaction to have been defective.

Weinschel Engineering reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

This warranty is expressly in lieu of all other obligations or liabilities on the part of Weinschel Engineering.

Weinschel Engineering neither assumes nor authorizes any other person to assume for them any other liability in connection with the sale of their instruments and equipment.

Calibration standards as applicable are

traceable to the National Bureau of Standards.

Application Note No. 1

WEINSCHEL
ENGINEERING

SINGLE CHANNEL INSERTION LOSS TEST SET

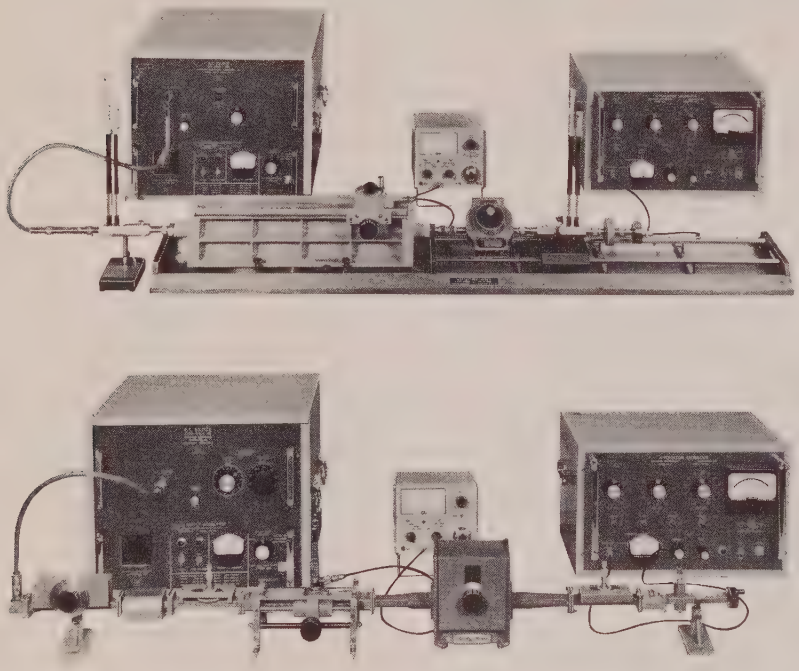


Figure Number 1.

INTRODUCTION

The single channel audio substitution system is the fastest and simplest method of making accurate rf insertion loss measurements. Using equipment specifically designed for this purpose, measurements can be made directly to 35 db with an accuracy of ± 0.02 * db per 10 db or ± 0.02 db whichever is greater. The resolution is ± 0.01 db. By applying rf substitution techniques this range usually can be extended to at least 55 db with only a small deterioration in accuracy.

This system is applicable to the measurement of insertion loss of coax or waveguide attenuators and other devices as well as to the measurement of antenna patterns and similar rf applications that require the precise determination of power ratios. The accuracy of the measurement is based principally on the square law characteristics of a barretter detector and the accuracy of audio substitution attenuators. Although the specific equipment listed covers the range from 50 mc to 60 gc, the method is applicable down to at least 1 mc and up to any frequency where the required accessory equipment is available.

In general, the single channel system has the following advantages over other techniques for the measurement of insertion loss:

1. Only one rf source is required.
2. Only commonly used microwave components are required as accessories.
3. Operating procedure is simple.
4. It is equally applicable in the laboratory, for quality control checks, or on the production line.

For applications where the accuracy, resolution or range of this system is insufficient, either the Weinschel Engineering Dual Channel System[1] or the Standard Attenuator Comparator[2] Model VM-1 is recommended.

* This error assumes the use of perfect auxiliary equipment. The measurement error for an average system including oscillator power drift, connector instability, etc., is ± 0.1 db per 10 db or ± 0.1 db whichever is greater.

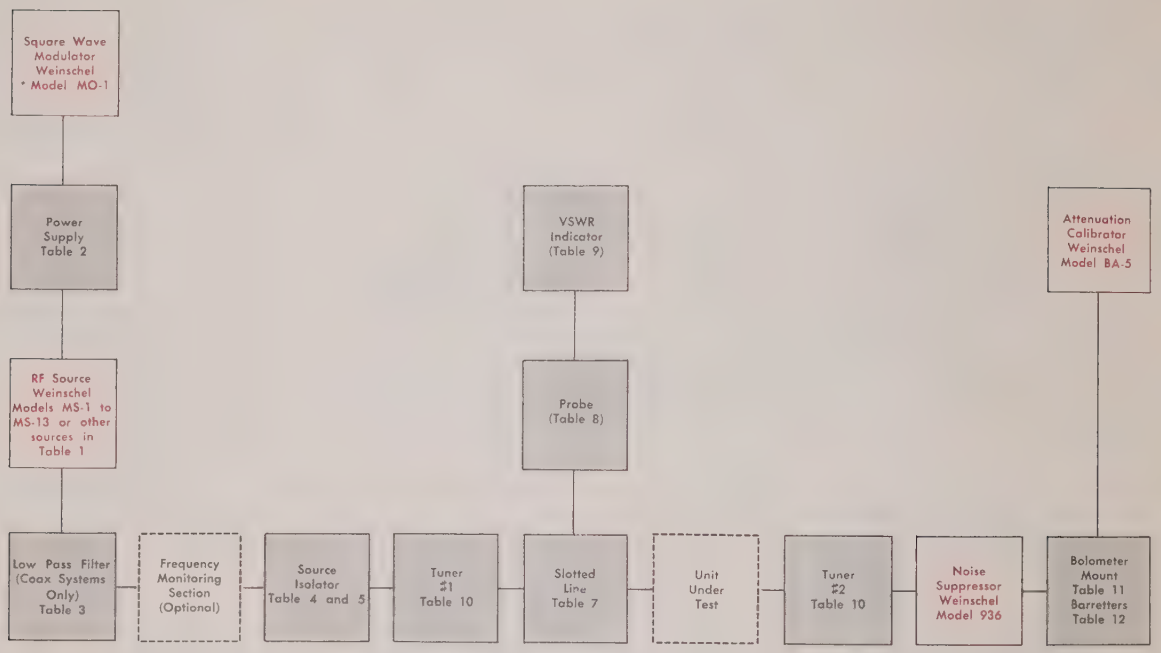

Square Wave Modulator Weinschel * Model MO-1
Power Supply Table 2
RF Source Weinschel Models MS-1 to MS-13 or other sources in Table 1
Low Pass Filter (Coax Systems Only) Table 3
Frequency Monitoring Section (Optional)
Source Isolator Table 4 and 5
Tuner #1 Table 10
VSWR Indicator (Table 9)
Probe (Table 8)
Slotted Line Table 7
Unit Under Test
Tuner #2 Table 10
Noise Suppressor Weinschel Model 936
Attenuation Calibrator Weinschel Model BA-5
Bolometer Mount Table 11 Barretters Table 12
* Use Model MO-1 Modulator if power supply used does not have a tuning fork stabilized oscillator

Figure Number 2. Block Diagram of a Typical Single Channel Insertion Loss Test System.

DESCRIPTION OF THE SYSTEM

A block diagram of a typical single channel insertion loss test set is shown in Fig. 2. The 100% square wave modulated rf signal from a well-regulated and isolated source is fed through a single line of rf components to a terminating barretter mount where the rf is converted into an audio voltage. The actual measurement of rf attenuation is then made by adjusting calibrated audio attenuators in order to keep the detected audio signal constant at the output of the Model BA-5 Attenuation Calibrator. Both the accuracy of the audio attenuator and the conversion law of the detector are the important factors in determining the measurement accuracy of such an audio substitution system.

In order to be useful in this application, the terminating detector must have a known conversion law. The operation of the system places the signal levels at the detector in the microvolt range and at such levels most detectors exhibit square law conversion behavior, that is the output *audio voltage* is proportional to the input *rf power*. When such a detector is used, it is clear that changes of power level in the rf circuit can be accurately measured in the audio circuit.

Curves showing the low power detection characteristics of the two most commonly used detectors, the Wollaston wire barretter and the silicon crystal, are shown in Figs. 4 and 5. Because of the lower audio output voltage at which the crystal departs from square law and also because of its higher noise level, the dynamic range of accurate measurements using crystals is smaller than with barretters[6]. A further disadvantage of crystals is that their characteristics can be drastically altered by overload powers or by aging. Because of this the exact audio level of a crystal for accurate square law operation is

Figure Number 3. Optional Frequency Monitoring Section

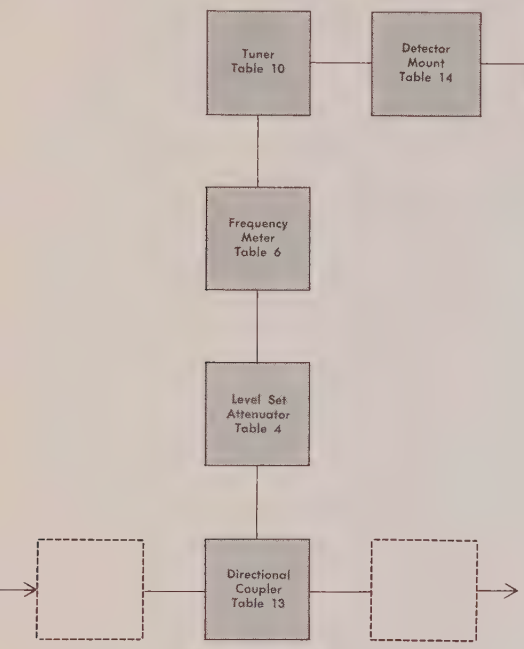


Figure Number 4. Experimental vs. Theoretical Deviation from Square Law as Function of Peak Power for a Barretter.

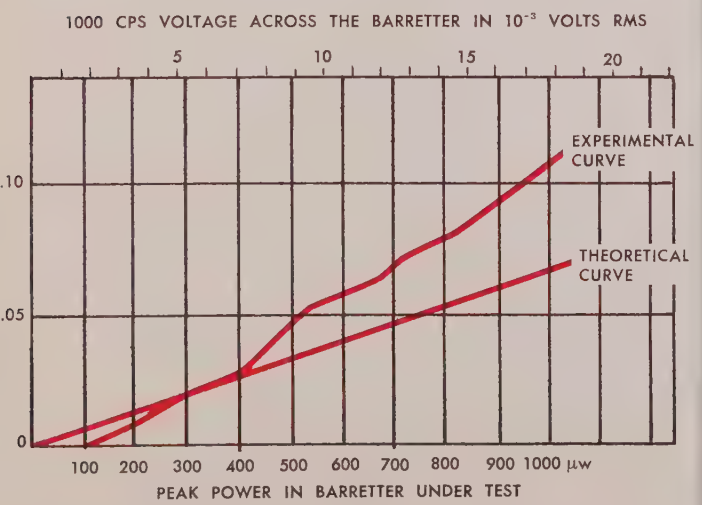


Figure 5A. Deviation from Square Law for IN32 Crystal.

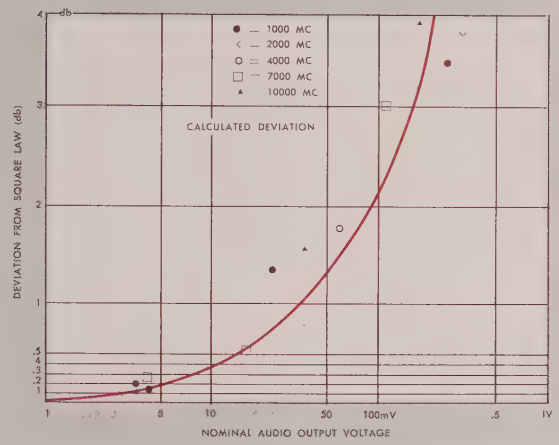
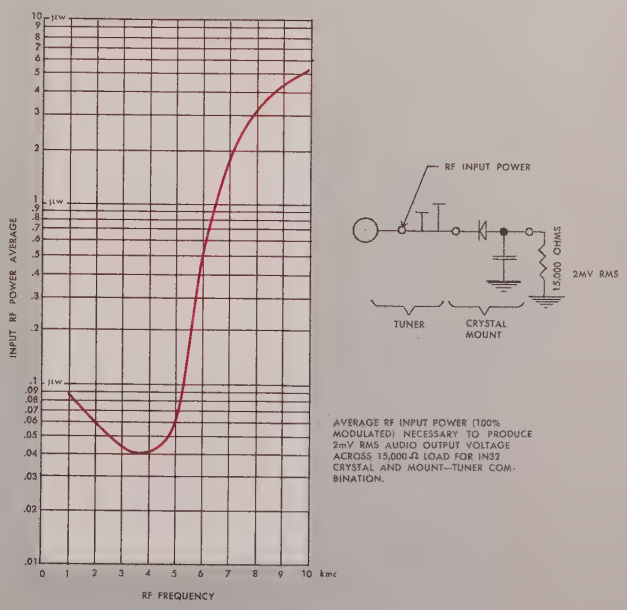


Figure 5B. RF Power Needed to Produce Constant Audio-output Voltage as a Function of RF Frequency.


10 mw
1 μw
.1 μw
INPUT RF POWER AVERAGE
0 1 2 3 4 5 6 7 8 9 10 kmc
RF FREQUENCY
RF INPUT POWER
15,000 OHMS
2MV RMS
TUNER
CRYSTAL MOUNT
AVERAGE RF INPUT POWER (100% MODULATED) NECESSARY TO PRODUCE 2mV RMS AUDIO OUTPUT VOLTAGE ACROSS 15,000Ω LOAD FOR IN32 CRYSTAL AND MOUNT—TUNER COMBINATION.

known only if a calibration is made prior to the use of a particular element. Barretters, on the other hand, have characteristics that are almost constant with time and from unit to unit. Being bolometric elements, their response is almost independent of rf frequency. For these reasons, barretters are nearly always used in preference to crystals when making precision measurements.

The actual measurement of insertion loss is made by first establishing an audio level on the Model BA-5 Attenuation Calibrator without the unknown in the rf circuit and then re-establishing this level by removing audio attenuation after the rf unit is inserted. The measured attenuation in this matched system is actually the insertion loss of the device under test as defined by IRE standards[3] and is made up of two independent losses. One is the loss of power due to dissipation in the resistance of a conductor or in a dielectric, and the second is power that is reflected because the unit under test is not perfectly matched. A curve showing the simple reflected loss as a function of mismatch is shown in Fig. 6.

Low level audio voltages must be measured accurately in this system and it is, therefore, important to eliminate line frequency and 1000 cps ground currents from the detector system. Such ground currents can flow through the rf plumbing between the various electronic instruments and may cause measurement errors. More recently, with the common use of three wire power cords on electronic instruments, this has become a serious problem. The Weinschel Engineering Model 936 Noise Suppressor shown attached to the bolometer in Fig. 2 isolates the detector from such ground currents and thereby greatly increases the reliability of the measurement.

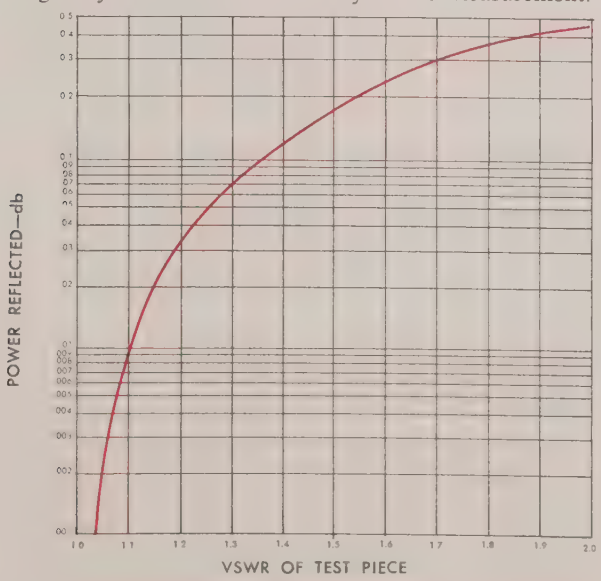


Figure Number 6. Reflected Power vs. Mismatch

PROCEDURE

The following step by step procedure is recommended for use in measuring the insertion loss of an rf component.

1. Using appropriate instruments selected from those listed in Tables 1 through 14, set up the equipment as shown in Fig. 2.
2. Set the 1000 cps modulated rf source to the frequency at which measurements are to be made. Adjust tuners No. 1 and 2 so that readings are obtained on the standing wave amplifier and on the Model BA-5, taking care that neither is overloaded.
3. Using the slotted line and standing wave amplifier, match the terminating bolometer with tuner No. 2.
4. Match the generator buffer pad by removing it together with tuner No. 1 and then inserting it after the slotted line. Use the matched bolometer as a termination. After matching, replace the combination in the original position being careful not to move the tuning stubs.

NOTE

This tuning procedure assumes that the buffer pad has at least 10 db and preferably 20 db attenuation, or if a ferrite isolator is used, that the isolation is a minimum of 20 db.

5. Set the gain controls on the Model BA-5 at the minimum (counterclockwise) position and all audio attenuators at 0 db. Adjust the rf power level until the meter on the BA-5 is set at the 2 db mark. The BA-5 is designed so that with this adjustment the barretter will automatically operate in the square law region. This is about equivalent to 200 mw peak power into the barretter and about 3 mV rms 1000 cps into the BA-5.
6. Set the audio attenuators on the BA-5 to a reference setting higher than the expected insertion loss of the rf device being measured. Then adjust the audio gain for a convenient reference reading on the output meter of the BA-5.
7. After carefully noting the meter and attenuator settings on the BA-5, insert the unit under test and restore the reference meter reading by removing audio attenuation. The insertion loss of the unit under test is equal to the difference observed between the reference and final attenuator settings on the BA-5.
8. Remove the test unit and recheck the original reference settings.

Using this procedure, the accuracy of the measurement is usually controlled by the stability of the rf source, the stability or repeatability of the rf connectors, and the ability of the operator to return the meter to the reference setting.

The one step attenuation range that can be covered is limited by the spread between the maximum signal that can be used in the bolometer and the noise. In practice, this range is approximately 35 db. It can be extended 10 db by operating out of the square law region of the barretter as explained in the instruction manual for the BA-5. However, a more desirable technique for extending the range is the use of partial rf substitution. In most cases, partial rf substitution can extend the range by 20 db to a total of 55 db.

When measuring fixed attenuators, this is accomplished by first carefully calibrating a "standard" 20 db attenuator using the procedure already described. This attenuator is kept in the rf circuit after the slotted line as the reference level is set: The "standard" is then replaced by the unknown and the BA-5 rebalanced in the normal way. The insertion loss of the test unit is equal to the sum of the insertion loss of the "standard" and the difference in audio attenuator settings on the BA-5. When a variable attenuator is to be calibrated, the "standard" can be the 20 db position on the attenuator and the range from 20 to 55 db can be measured in one step using the BA-5.

In order to use partial rf substitution, the rf generator must be able to supply more power than is required for the normal insertion loss measurement. For the commonly used barretters operating at a 200 microwatt level, at least 20 milliwatts of power must be available at the input to the 20 db substitution "standard' in order to make the measurement. If a 10 db generator buffer pad is used, the source must have an output of 200 mw. A ferrite isolator can be used to isolate the generator and reduce the required power level.

ELECTRONIC INSTRUMENTS

Microwave plumbing and electronic instruments suitable for use in the Single Channel Insertion Loss Test Set are shown in Tables 1 through 14. The Model BA-5 Attenuation Calibrator, the rf sources, and the audio modulator are vital components necessary for accurate measurements. These are described below:

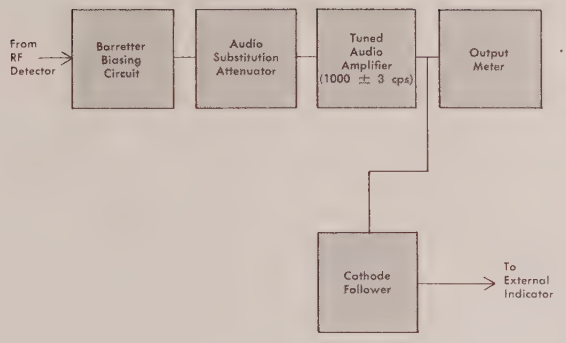


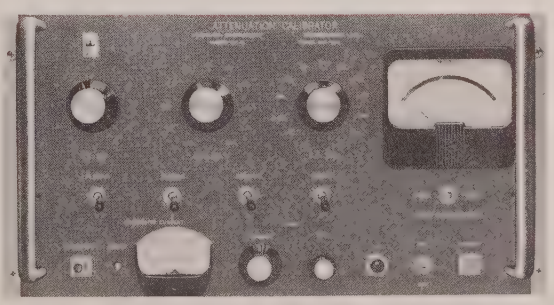
Figure Number 7. Block Diagram of Model BA-5 Attenuation Calibrator

A. ATTENUATION CALIBRATOR

The Weinschel Engineering Model BA-5 Attenuation Calibrator is unique in that it is the only commercial instrument specifically designed for making precision microwave attenuation measurements using the audio substitution technique. A block diagram of the instrument is shown in Fig. 7. The precision 2000 ohm audio attenuator is placed *in front* of the low noise, high gain, 1000 cps tuned amlifier. With this attenuator-amplifier arrangement, any slight nonlinearity of the amplifier contributes no error since the amplifier operates at a fixed level during any one measurement.

The audio attenuators are made using wirewound resistors with ± 0.1% tolerance and are combined so that a 30 db (rf equivalent) step is accurate to ± 0.02 db. The attenuator is continuously variable over a 52 db range at rf and has a resolution of 0.002 db. Special long life switches are used which are designed to maintain the accuracy of the instrument over years of normal use. The attenuator is calibrated directly in rf attenuation assuming the use of square law detectors.

Figure Number 8. Model BA-5, Attenuation Calibrator



A metered, internal-regulated, constant-current bolometer bias supply provides currents in the range from 3 to 9 ma dc. Protective circuits are included to prevent barretter burnout while connecting or disconnecting the barretter or turning the instrument on or off. Although intended primarily for use with barretters, the BA-5 can also be used with crystals.

The detected output of the amplifier is displayed on a large mirror-backed meter calibrated in db and VSWR. A two position front panel switch can be used to set the meter time constant. The undetected output, fed through a cathode follower, is also available at the front panel.

B. RF SOURCE—MODULATOR

The rf power source must be stable in both frequency and power output in order to achieve the highest measurement accuracy. It must also be 100% square wave modulated with a very stable 1000 cps source.

It is recommended that the appropriate Weinschel Engineering RF Source Models MS-8, -9, -10, -11, -12, or -13 be used together with the Model MO-3 Power Supply. This supply has closely regulated voltages and a tuning fork stabilized 1 kc modulator. If these sources are not available, however, one of the other sources shown in Table 1 can be used with a Weinschel Engineering Model MO-1 Modulator. The MO-1 uses a tuning fork stabilized oscillator and the output is sufficient to modulate most test oscillators. The modulation frequency of either the MO-1 or the MO-3 is held to 1000 ± 0.1 cps.

CONCLUSION

Each year the need both in standards laboratories and on the production line is for the more accurate measurement of insertion loss and for a wider dynamic range. Weinschel Engineering has endeavored to meet this challenge by the development of instruments designed for this specific measurement.

This application note is one in a series discussing various systems and techniques for measuring power and power ratios. Discussed above is a system for the direct measurement of rf insertion loss up to 35 db with an accuracy of ± 0.02 db/10 db in a perfect system and ± 0.1 db/10 db in an average system including oscillator power drift. For applications requiring greater resolution and accuracy, but with the same dynamic range, the Dual Channel Insertion Loss Test Set[1] is recommended. For applications requiring the highest accuracy, resolution and a one step range up to approximately 90 db, the Weinschel Engineering Model VM-1 Standard Attenuator Comparator[2] is recommended.

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1. Weinschel Engineering, Application Note No. 4, "Dual Channel Insertion Loss Test Set".
2. Weinschel Engineering Specification Sheet, Model VM-1, "Standard Attenuator Comparator", Bulletin No. 102R8.
3. "IRE Standards on Antennas & Waveguides: Waveguide and Waveguide Component Measurements, 1959", Proceedings of the IRE, Vol. 47, No. 4, April 1959.
4. G. U. Sorger and B. O. Weinschel, "Precise Insertion Loss Measurements Using Imperfect Square Law Detectors and Accuracy Limitations Due to Noise," pp. 55-68, IRE *Transactions on Instrumentation,* October 1955, reprinted as Weinschel Engineering Note No. 1.
5. B. O. Weinschel, "Insertion Loss Test Sets Using Square Law Detectors," pp. 160 to 164, IRE *Transactions on Instrumentation,* October 1955, reprinted as Weinschel Engineering Note No. 2.
6. G. U. Sorger and B. O. Weinschel, "Comparison of Deviations from Square Law for RF Crystal Diodes and Barretters, "IRE *Transactions on Instrumentation,* Vol. I-8, Number 3, December 1959, reprinted as Weinschel Engineering Note No. 7.
7. G. U. Sorger, "The Thermal Time Constant of a Bolometer", pp. 165-170, IRE *Transactions on Instrumentation,* October 1955, reprinted as Weinschel Engineering Note No. 3.

TABLE 1: R. F. SOURCES

Frequency Range (GC)	Manufacturer*	Model Number	Power Supply Required
0.25 — 0.75	Weinschel	MS-1	None
0.05 — 0.25	Weinschel	MS-12	Weinschel Model MO-3**
			Weinschel Model MO-5**
0.75 — 0.92	Weinschel	MS-2	None
0.25 — 0.92	Weinschel	MS-13	Weinschel Model MO-3**
			Weinschel Model MO-5**
0.90 — 2.00	Weinschel	MS-3	None
0.90 — 2.20	Weinschel	MS-8	Weinschel Model MO-3**
			Weinschel Model MO-5**
2.00 — 4.20	Weinschel	MS-9	Weinschel Model MO-3**
			Weinschel Model MO-5**
4.0 — 7.30	Weinschel	MS-10	Weinschel Model MO-3**
			Weinschel Model MO-5**
7.2 — 10.50	Weinschel	MS-11	Weinschel Model MO-3**
			Weinschel Model MO-5**
8.2 — 12.4	Varian	X-13	See Table 2
10.0 — 15.0	Weinschel	MS-16	Weinschel Model MO-5**
12.4 — 17.5	Varian	X-12	See Table 2
15.0 — 21.00	Weinschel	MS-17	Weinschel Model MO-5**
22.0 — 25.0	Raytheon	2K33B	See Table 2
22.0 — 25.0	Varian	VA-96	See Table 2
22.3 — 30.0	Raytheon	QKK-289	See Table 2
29.7 — 33.5	Raytheon	QKK-290	See Table 2
33.5 — 36.2	Raytheon	QKK-291	See Table 2
35.1 — 39.7	Raytheon	QKK-292	See Table 2
37.1 — 42.6	Raytheon	QKK-293	See Table 2
41.7 — 50.0	Raytheon	QK-294	See Table 2
50.0 — 60.0	Raytheon	QK-295	See Table 2

*See Code of Manufacturers, Table 15.
**Includes Modulator.

TABLE 2: KLYSTRON POWER SUPPLIES

Manufacturer*	Model Number
PRD	815
Sperry	62A1
FXR	Z815B

*See Code of Manufacturers, Table 15.

TABLE 3: LOW PASS FILTERS

Cutoff Frequency (GC)	Manufacturer*	Model Number
.044	Sierra	184
.076	Sierra	184
.135	Sierra	184
.230	Sierra	184
.400	Sierra	184
.400	Bird	844
.500	Narda	3010-500
.7	H-P	360-A
1.0	Narda	3010-1000
1.2	Bird	819-1200
1.2	H-P	360-B
2.1	Narda	3010-2100
2.2	H-P	360-C
4.1	H-P	360-D
4.2	Narda	3010-4200

*See Code of Manufacturers, Table 15.

TABLE 4: COAXIAL AND WAVEGUIDE ATTENUATORS

COAXIAL

Frequency Range (GC)	Manufacturer*	Model Number
DC-1.0	Weinschel	Model 905 (Variable)
DC-1.0	Weinschel	Model 10 (Fixed)
DC-3.0	Weinschel	Model 50 (Fixed)
DC-5.0	Weinschel	Model 650 (Fixed)
1.0-12.4	Weinschel	Model 210 (Fixed)
1.0-12.4	Weinschel	Model 503 (Fixed)

WAVEGUIDE

Frequency Range (GC)	Manufacturer's* Model Number			
	FXR	H-P	Narda	PRD
2.6 — 3.95	S-155-A	S-375-A	734	171
3.95 — 5.85	H-155-A	G-375-A	733	162
5.85 — 8.2	C-155-A	J-375-A	732	161
7.05 — 10.0	W-155-A	H-375-A	731	160
8.2 — 12.4	X-155-A	X-375-A	730	159
12.4 — 18.0	Y-151-A	P-375-A	729	189
18.0 — 26.5	K-151-A	K-375-A	728	190
26.5 — 40.0	U-151-A	R-375-A	V-727	191
33.0 — 50.0	Q-151-A		Q-727	
50.0 — 75.0	M-151-A		M-727	179
60.0 — 90.0	E-151-A		E-727	

*See Code of Manufacturers, Table 15.

TABLE 5: ISOLATORS

Manufacturer*	Model Number	Manufacturer	Model Number
Rantec Airtron Kearfott Cascade Raytheon	Consult Manufacturer for Proper Model for Your Needs	Sylvania TRG Inc. Micromega Narda PRD FXR	Consult Manufacturer for Proper Model for Your Needs

*See Code of Manufacturers, Table 15

TABLE 6: FREQUENCY METERS

Frequency Range (GC)	Manufacturer's* Model Number			
	FXR	H-P	Narda	PRD
0.2 — 0.5			804	
0.250 — 1.0				587A
0.5 — 2.4			805, 806	
1.0 — 4.0	N410A	536A		
3.95 — 5.85	H410A	G532A		532
5.85 — 8.20	C410A	J532A		533
8.20 — 12.4	X410A	X532A	840	535
12.4 — 18.0	Y410A	P532A		536
18.0 — 26.5	K410A	K532A		537
26.5 — 40.0	U410A	R532A		538
33.0 — 50.0	Q410		Q807	
50.0 — 75.0	M410		M807	
60.0 — 90.0	E410		E807	

*See Code of Manufacturers, Table 15.

TABLE 7: SLOTTED LINES

COAXIAL

Frequency Range (GC)	Manufacturer*	Model Number
0.375 — 3.0	Alford	1026B-16[1]
1 — 4.0	Alford	2181-6[2]
5 — 4.0	H-P	805-C
45 — 4.0	Narda	230-N, 230-C, 230-5/8, 230-7/8, 230-SC
1.0 — 4.0	FXR	N-101-A[3]
1.0 — 4.0	PRD	215-A[3]
1.5 — 12.4	Narda	231-N, 231-C, 231-TNC[3]
3.0 — 12.0	H-P	806-B[3]
4.0 — 10.0	FXR	N-101-B[4]
4.0 — 10.0	PRD	205-A[3]

WAVEGUIDE

Frequency Range (GC)	Manufacturer's* Model Number			
	FXR	Narda	H-P	PRD
2.60 — 3.95	S-101-A[3]	224[4]	S-810[4]	209-A[3]
3.95 — 5.85	H-101-A[3]	223[3]	G-810-B[4]	201-A[3]
5.85 — 8.2	C-101-A[3]	222[4]	J-810-B[4]	204-B[3]
7.05 — 10.0	W-101-A[3]	221[3]	H-810-B[4]	202-B[3]
8.2 — 12.4	X-101-A[3]	220[4]	X-810-B[4]	203-D[3]
12.4 — 18.0	Y-102-A	219[3]	P-810-B[4]	210-A
18.0 — 26.5	K-102-A	218[5]	K-815-B[4]	211-A
26.5 — 40.0	U-102-A[5]	V-217[5]	R-815-B[4]	212-A
33.0 — 50.0	Q-103-A[5]	Q-217[5]		
50.0 — 75.0	M-103-A[5]	M-217[5]		216
60.0 — 90.0	E-103-A[5]	E-217[5]		

*See Code of Manufacturer, Table 15.

[1] Requires one Type 1122C Type N Tapered Reducer.
[2] Requires one Type 2170 Type N Tapered Reducer
[3] Requires Tuning Probe, See Table 8.
[4] Used with Universal Probe Carriage and Tuning Probe, See Table 8.
[5] Requires Detector Mount

TABLE 8: PROBES

Freq. Range (GC)	Manufacturer*	Model Number
1.0 — 12.4	FXR	B-200-A tunable
1.0 — 12.4	PRD	250-A tunable
9 — 18.0	Narda	229 tunable
3.0 — 18.0	H-P	444-A untuned
18.0 — 40.0	H-P	446-B untuned

*See Code of Manufacturers, Table 15

TABLE 9: VSWR INDICATORS

Manufacturer*	Model Number
H-P	415-C
PRD	277B
FXR	B-812-A
Narda	441B

*See Code of Manufacturers, Table 15

TABLE 10: TUNERS

COAXIAL TUNERS		
Frequency Range	**Manufacturer**	**Model Number**
40 MC — 400 MC	Weinschel	DS-109H
20 GC — 2.0 GC	Weinschel	DS-109LL
40 GC — 4.0 GC	Weinschel	DS-109L
75 GC — 10.0 GC	Weinschel	DS-109

WAVEGUIDE TUNERS				
Frequency Range (GC)	**Manufacturer's* Model Number**			
	H-P	**PRD**	**Narda**	**FXR**
2.60 — 3.95	S-870-A	309-A	964	S-311-A S-312-A
3.95 — 5.85	G-870-A	300-A	963	H-311-A H-312-A
5.85 — 8.20	J-870-A	305-A	962	C-311-A C-312-A
7.05 — 10.0	H-870-A	302-B	961	W-311-A W-312-A
8.2 — 12.4	X-870-A X-880-A	303-A	960	X-311-A X-312-A
12.4 — 18.0	P-870-A P-880-A	314-A	959	Y-311-A Y-312-A
18.0 — 26.5	K-870-A K-880-A	313-A	958	K-312-B
26.5 — 40.0	R-870-A R-880-A	312-A	V-957	U-312-B
33.0 — 50.0			Q-957	Q-312-B
50.0 — 75.0		323	M-957	M-312-B
60.0 — 90.0			E-957	E-312-B

*See Code of Manufacturers, Table 15.

TABLE 11: BOLOMETER MOUNTS

COAXIAL BOLOMETER MOUNTS			
Frequency Range (GC)	**Manufacturer***	**Model Number**	**Barretter Model Number**
0.01 — 10	Weinschel	926[1]	943

WAVEGUIDE BOLOMETER MOUNTS					
Frequency Range (GC)	**Manufacturer's* Model Number**				
	FXR	**H-P**	**Narda**	**PRD**	**Sperry**
2.60 — 3.95	S-207A	S-485A	534	S6608	33S2
3.95 — 5.85	H-207A	G-485A	533	G6608	33C2
5.85 — 8.20	C-207A	J-485A	532	C6608	33G2
7.05 — 10.00	W-207A	H-485A	531	H6608	33H2
8.20 — 12.40	X-207A	X-485A	530	X6608	33X2
12.4 — 18.0	Y-205		529	620	
18.0 — 26.5	K-205			620F1	
26.5 — 40.0	U-205			618F1	
33.0 — 50.0	Q-206				
50.0 — 75.0	M-206				
60.0 — 90.0	E-206				

*See Code of Manufacturers, Table 15.

[1] This unit has a built-in noise suppressor equivalent to Weinschel Model 936N. It is fixed tuned and has a VSWR below 1.5 over the entire frequency range.

TABLE 12: BARRETTERS

Type	Description	DC Bias (MA)	Manufacturer's* Model Number					Special Features
			Weinschel	FXR	Narda	PRD	Sperry	
1	1N21	4 5		Z-220-C	N-610-B-4.5	610A		
2	1N21	8 75		Z-220-A	N-610-B		38B7	
2	1N21	8 25		Z-220-B				
3	1N21	8 75			N-610-B-100			100 ohms
4	193" dia. 812" long	8.75			N-821-B		38B1	
5	1N26	4.5				614		12.4-26.5 GC
5	1N26	8.75		Z-221-A				12.4-40 GC
6	Modified	8 75		Z-221-B				26.5-40 GC
7	1N53	8.75		Z-222-A				26.5-90 GC
8	Special Mica Strip	4.5			N-603-4.5	631-C		0.5-10 GC
9	"	8.75			N-603			0.5-10 GC
10	"	4.5				617		18-40 GC
11	Miniature	8.75			N-604			8.2-18 GC (Low Inductance)
12	1N21	8.75			N-605			1.1-10 GC
13	Special Disc		943					.01-10 GC Coax.

*See Code of Manufacturers, Table 15.

TABLE 13: DIRECTIONAL COUPLERS

COAXIAL

Frequency Range (GC)	Manufacturer*	Model Number
225 — 460	Narda	3000-10
460 - 950	Narda	3001-10
950 — 2 0	Narda	3002-10
2 0 - 4 0	Narda	3003-10
4 0 — 8 0	Narda	3044-10
7 0 — 11 0	Narda	3045-10

WAVEGUIDE

Frequency Range (GC)	Manufacturer's* Model Number				
	H-P	FXR	PRD	Narda	Sperry
2 6 — 3 95	S752C	S610C	409	1074-10	45S1
3 95 — 5 85	G752C	H610C	410	1073-10	45C1
5 85 — 8 2	J752C	C610C	411	1072-10	45G1
7 05 — 10 0	H752C	W610C	412	1071-10	45H1
8 2 — 12 4	X752C	X610C	408	1070-10	45X1
12 4 — 18 0	P752C	Y610C	413	1069-10	45U1
18 0 — 26 5	K752C	K610C		1068-10	45K1
26 4 — 40 0	R752C	U610C		V1067-10	45V1
50 0 — 75 0		M610C		M1067-10	

*See Code of Manufacturers, Table 15.

TABLE 14: DETECTOR MOUNTS

COAXIAL

Frequency Range (GC)	Manufacturer* and Model Number	Crystal Type
0.01 — 10	H-P, Model 420A	Modified 1N26
0.01 — 1.0	PRD, Model 641	Sylvania 1N21
0.5 — 1.0	Am. Elect. Lab., Model C1000	Micro Assoc. MA408
1.0 — 10.0	Weinschel, Model 578	Micro Assoc. MA408

WAVEGUIDE

Frequency Range (GC)	Manufacturer*, Model Number and Crystal Type									
	Aircom	Crystal Type**	PRD	Crystal Type**	Micro Assoc	Crystal Type**	FXR	Crystal Type**	H-P	Crystal Type**
3.95 — 5.85	157-C	1N23								
5.85 — 8.2	157-XC	1N23								
8.2 — 12.4	157-X	1N23			536C	1N23	X211A	1N23	X421A	1N26 (mod.)
12.4 — 18.0	157-KU	1N78	618A	1N78			Y265B	1N26	P421A	1N26 (mod.)
18.0 — 26.5	157-K	1N26	621	1N26	103EC	1N26	K265B	1N26		
26.5 — 40.0	157-KA	1N53			513E	1N53	U206B	1N53		
33.0 — 50.0	157-V	1N53					Q206B	1N53		
50.0 — 75.0	157-W	1N53			569	1N53	M206B	1N53		

*See Code of Manufacturers, Table 15.
**Sylvania Model Number listed.

TABLE 15: CODE OF MANUFACTURERS*

Abbreviation	Manufacturer's Name and Address
Aircom	Aircom, Inc. 48 Cummington Street Boston, Mass.
Airtron	Airtron Division of Litton Industries 200 East Hanover Avenue Morris Plains, N. J.
Alford	Alford Manufacturing Company 299 Atlantic Ave. Boston, Mass.
Am. Elect. Lab.	American Electronics Lab., Inc. 121 North 7th Street Philadelphia 6, Pa.
Bird	Bird Electronics Corp. 30303 Aurora Road Cleveland 39, Ohio
BJ Electronics	BJ Electronics, Division of Borg-Warner Corp. 3300 Newport Boulevard Santa Anna, Calif.
Cascade	Cascade Research Division, Lewis & Kaufman Electronics Corp. 5245 San Fernando Road, W. Los Angeles, Calif.
FXR	FXR, Division of Amphenol Borg Electronics Corp. 33 E. Franklin Street Danbury, Conn.
H-P	Hewlett-Packard Co. 1501 Page Mill Road Palo Alto, Calif.
Kearfott	Kearfott Division, General Precision, Inc. 14844 Oxnard Street Van Nuys, Calif.
Micro Assoc.	Microwave Associates, Inc. Northwest Industrial Park Burlington, Mass.
Micromega	Micromega Corp. 4134 Del Rey Avenue Venice, Calif.
Narda	Narda Microwave Corp. Plainview, N. Y.
PRD	PRD Electronics 202 Tillary Street Brooklyn, N. Y.
Rantec	Rantec Corp. Craftsman Center Calabasas, Calif.
Raytheon	Raytheon Co. Microwave and Power Tube Division Foundry Avenue Waltham 54, Mass.
Sierra	Sierra Electronics Corp., Division of Philco Corp. 3885 E. Bohannon Drive Menlo Park, Calif.
Sperry	Sperry Microwave Electronics Co., Division of Sperry Rand Corp. P.O. Box 1828 Clearwater, Florida
TRG	TRG Inc. 2 Aerial Way Syosset, N. Y.
Varian	Varian Associates 611 Hansen Way Palo Alto, Calif.

*This list does not constitute an endorsement

APPLICATION NOTE NO. 1

WEINSCHEL ACCESSORIES

Weinschel Engineering produces a complete line of precision accessories for use with the Single Channel Insertion Loss Test Set that has been described in the Application Note. Included among these accessories are both coaxial and waveguide noise suppressors, coaxial double stub tuners, bolometer mounts, and fixed and variable coaxial attenuators.

All Weinschel instruments and accessories are designed and manufactured to meet the most exacting requirements. Your assurance of quality and precision is a three-step inspection program. All purchased components and materials are inspected as they are received at Weinschel, and all instruments and components are inspected during various stages of manufacture. Completed items must then pass a rigid final inspection which is followed by careful calibration on the most precise measurement instrument available.

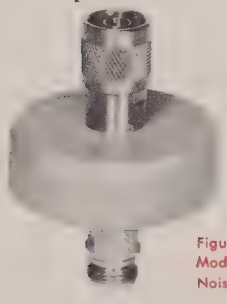

Figure Number 9.
Model 936N, Coaxial
Noise Suppressor

Figure Number 10.
Model 936X, Waveguide
Noise Suppressor

Figure Number 11.
Model DS109,
Double Stub Tuner

For the utmost in reliability and precision, a complete system of Weinschel instruments and accessories is unsurpassed.

We invite you to write for complete specifications on Weinschel precision accessories.

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Application Note No. 4

WEINSCHEL
ENGINEERING

DUAL CHANNEL INSERTION LOSS TEST SET

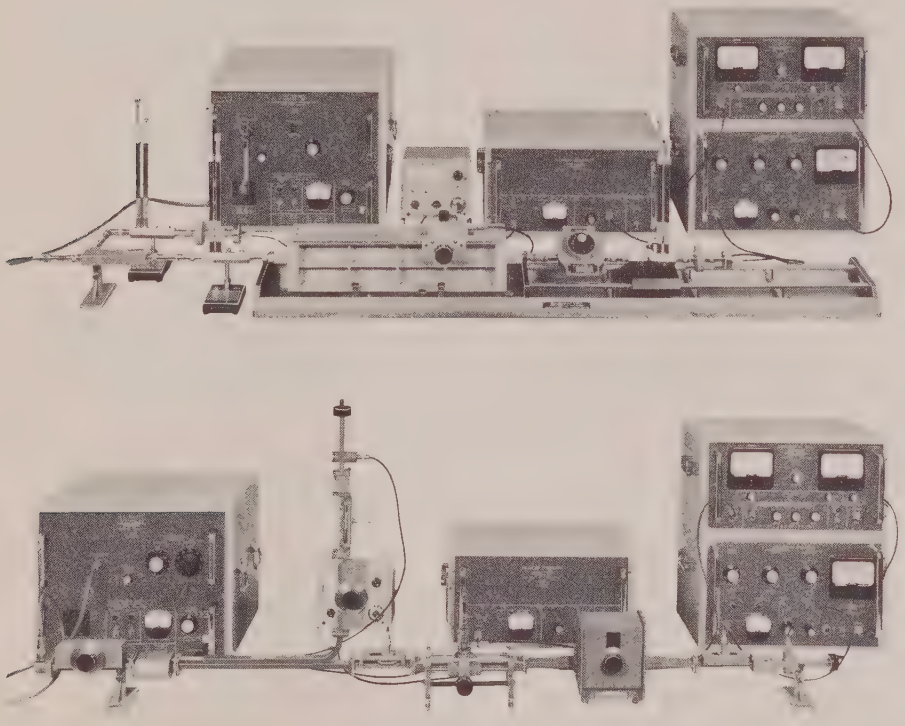


Figure Number 1

INTRODUCTION

The virtual elimination of errors caused by oscillator power drift and the utilization of the tremendous resolution possible with null detection, makes the Dual Channel Insertion Loss Test Set a powerful tool for the precise calibration of attenuators and the determination of the usually smaller insertion loss of cable assemblies, switches, and similar devices. The system to be described permits direct measurement of insertion losses up to 35 db with an accuracy of 0.02 db per 10 db.* Using rf substitution this range can be extended to 55 db. Measurements can be repeated to 0.01 db per 10 db and the resolution is approximately 0.001 db.

Because oscillator power drift is automatically nullified, this parallel audio substitution system can be used to make direct precise measurements of the small losses in cables, rotary joints, and similar devices.

The calibration accuracy is based principally on the square law detection characteristics of barretters and the accuracy of audio attenuators. This system uses the recognized principles of audio substitution and is an extension of the basic single channel audio substitution system described in Weinschel Engineering Application Note No. 1[1].

Although the particular rf equipment described is for the frequency range from 50 to 60,000 mc, the method is applicable at higher and lower frequencies.

* Or 0.01 db whichever is greater.

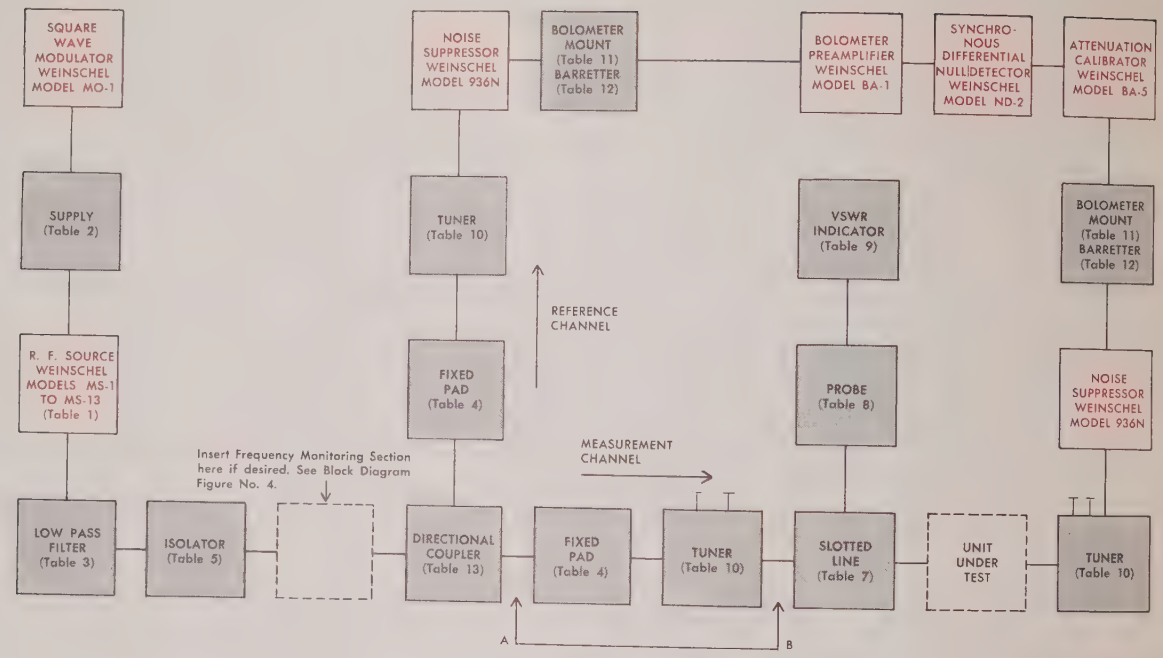

SQUARE WAVE MODULATOR WEINSCHEL MODEL MO-1
SUPPLY (Table 2)
R. F. SOURCE WEINSCHEL MODELS MS-1 TO MS-13 (Table 1)
LOW PASS FILTER (Table 3)
ISOLATOR (Table 5)
Insert Frequency Monitoring Section here if desired. See Block Diagram Figure No. 4.
NOISE SUPPRESSOR WEINSCHEL MODEL 936N
BOLOMETER MOUNT (Table 11) BARRETTER (Table 12)
TUNER (Table 10)
FIXED PAD (Table 4)
REFERENCE CHANNEL
DIRECTIONAL COUPLER (Table 13)
FIXED PAD (Table 4)
MEASUREMENT CHANNEL
TUNER (Table 10)
BOLOMETER PREAMPLIFIER WEINSCHEL MODEL BA-1
SYNCHRO-NOUS DIFFERENTIAL NULL DETECTOR WEINSCHEL MODEL ND-2
ATTENUATION CALIBRATOR WEINSCHEL MODEL BA-5
VSWR INDICATOR (Table 9)
PROBE (Table 8)
SLOTTED LINE (Table 7)
UNIT UNDER TEST
BOLOMETER MOUNT (Table 11) BARRETTER (Table 12)
NOISE SUPPRESSOR WEINSCHEL MODEL 936N
TUNER (Table 10)
A
B

Figure Number 2: Block Diagram of Coaxial Dual Channel Insertion Loss Test Set

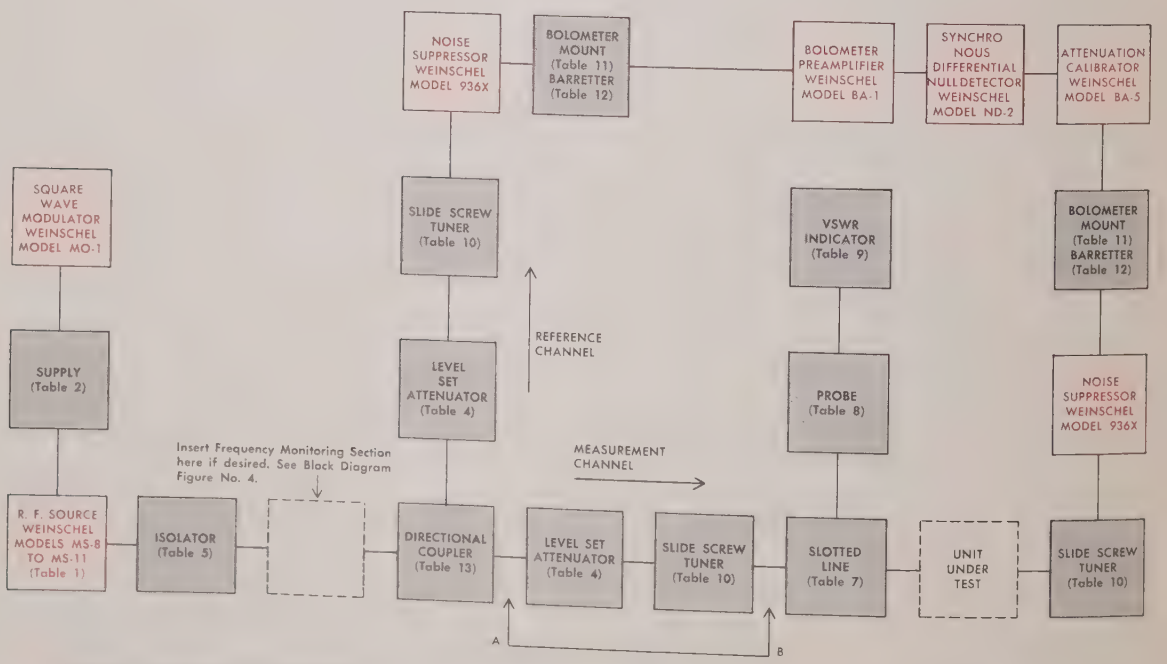

SQUARE WAVE MODULATOR WEINSCHEL MODEL MO-1
SUPPLY (Table 2)
R. F. SOURCE WEINSCHEL MODELS MS-8 TO MS-11 (Table 1)
ISOLATOR (Table 5)
Insert Frequency Monitoring Section here if desired. See Block Diagram Figure No. 4.
NOISE SUPPRESSOR WEINSCHEL MODEL 936X
BOLOMETER MOUNT (Table 11) BARRETTER (Table 12)
SLIDE SCREW TUNER (Table 10)
LEVEL SET ATTENUATOR (Table 4)
REFERENCE CHANNEL
DIRECTIONAL COUPLER (Table 13)
LEVEL SET ATTENUATOR (Table 4)
MEASUREMENT CHANNEL
SLIDE SCREW TUNER (Table 10)
BOLOMETER PREAMPLIFIER WEINSCHEL MODEL BA-1
SYNCHRO NOUS DIFFERENTIAL NULL DETECTOR WEINSCHEL MODEL ND-2
ATTENUATION CALIBRATOR WEINSCHEL MODEL BA-5
VSWR INDICATOR (Table 9)
PROBE (Table 8)
SLOTTED LINE (Table 7)
UNIT UNDER TEST
BOLOMETER MOUNT (Table 11) BARRETTER (Table 12)
NOISE SUPPRESSOR WEINSCHEL MODEL 936X
SLIDE SCREW TUNER (Table 10)
A
B

Figure Number 3: Block Diagram of the Waveguide Dual Channel Insertion Loss Test Set

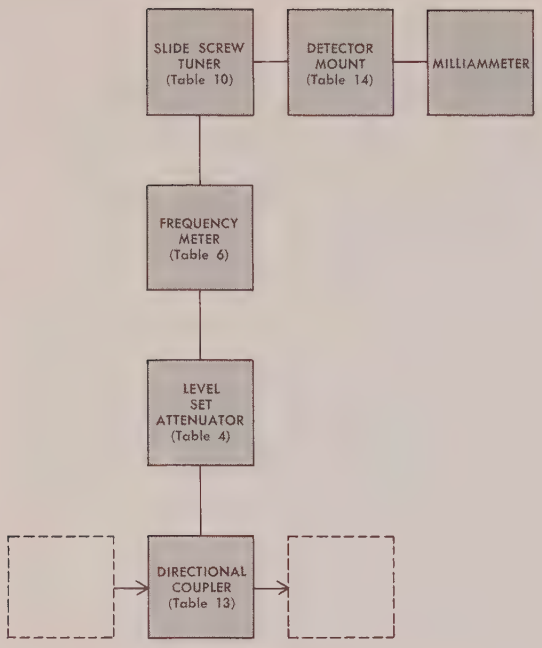


Figure Number 4: Block Diagram of the Frequency Monitoring Section

DESCRIPTION OF THE SYSTEM

Block diagrams of a coaxial line and a waveguide measuring system are shown in Figures 2 and 3. In both cases, the rf signal is first divided into two channels. The detected outputs of both channels are amplified and then balanced to zero in the Model ND-2 Synchronous Differential Null Detector. When the unit to be tested is inserted, enough audio attenuation is removed from the Model BA-5 Attenuation Calibrator to keep the signal levels at the ND-2 constant and balanced. The measured rf attenuation is then equal to the difference in the BA-5 attenuator settings. The measurement is substantially unaffected by changes in the rf level since both signals are derived from the same source and are balanced to zero in the output.

In both the coax and waveguide systems, a stable rf source at the selected frequency is 100% square wave modulated at 1 kc. After passing through a low pass rf filter and either a resistive or ferrite rf isolator, the signal is divided by a directional coupler into a *measurement channel* and a *reference channel*.

The signal in the *reference channel* passes through an isolation pad and then to a tuner which is used to optimize the power transfer to the terminating barretter. A Weinschel Model 936 Noise Suppressor is inserted before the barretter and the BA-1 Bolometer Preamplifier. This unit increases the reliability of the measurement by isolating audio currents that may flow in the ground system when certain combinations of equipment are used.

In the *measurement channel,* the rf power first goes to an isolation pad and then to a tuner. This tuner is used to present a matched generator at the insertion point but it is not needed when the isolation pad is well matched. A slotted line and a tuner to match the terminating barretter and noise suppressor completes the microwave plumbing in the *measurement channel.*

Both barretters must be operated in their square law region, i.e., the operating range where the voltage at the 1 kc modulation frequency developed across the barretter is proportional to the rf power absorbed by the barretter.[2,3] Operation in this region can be assured by keeping the audio output voltage from the barretters below 2 mv (rms).

PROCEDURE

To measure insertion loss, first the tuner and bolometer in the *reference channel* are put at the end of the slotted line in the *measurement channel* and the combination is tuned for optimum match. Then the terminating bolometer in the *measurement channel* is matched using the same slotted line. As a final tuning adjustment, the generator impedance in the *measurement channel* must be matched.

In order to do this, the equipment between points A and B in Figures 2 and 3 is taken out of the line, turned around and then put in place of the bolometer at the end of the slotted line. Using the tuned *measurement channel* bolometer as a termination, the impedance into the generator pad is matched with the tuner. This procedure assumes that the isolation of this pad or ferrite isolator is greater than 10 db.

Next, the rf level is checked to make certain that the bolometers are operating in the square law region. This is done by measuring the 1 kc audio voltage into the BA-5 and setting this level below 2 mv. The stabilized gain of the BA-5 is set so that at minimum gain and with the substitution attenuators set to zero a 2 mv signal will deflect the output meter to the 2 db point.

The precision audio attenuator in the BA-5 Attenuator Calibrator is then set at slightly more attenuation than the expected insertion loss of the unit to be tested or calibrated. Gain in the *reference channel* and the phasing adjustments on the ND-2 Differential Null Detector are used to produce a null reading on the ND-2. The unit to be tested is

then inserted in the *measurement channel* and audio attenuation is removed from the BA-5 until the null reading is restored on the ND-2. The rf attenuation is then equal to the difference in the audio attenuator markings on the BA-5.

RANGE EXTENSION

The procedure described above is for the direct measurement of insertion loss up to 35 db with an accuracy of 0.02 db per 10 db. To increase the range of insertion loss measurements, partial rf substitution can be used providing that the source has sufficient power output. For example, if the source has an output of 200 mw, the range can be extended 20 db to a total of 55 db with only a slight deterioration in accuracy. A lower power generator is satisfactory if ferrite isolators are used in place of the buffer attenuator pads.

In making extended range measurements using partial rf substitution, an accurately calibrated 20 db attenuator is put in the *measurement channel* and the initial system balance is made. The unit to be measured is then inserted and the calibrated rf attenuator is removed together with enough audio attenuation to rebalance the system. The value of the unknown attenuator is then equal to the sum of audio attenuation that was removed and the value of the calibrated attenuator.

If the attenuator under test is continuously variable the range can be extended by measuring the attenuation in two steps. In the first step 20 db is measured carefully several times and the attenuator dial position noted. The attenuator is then set at this point and the generator power increased to provide the original reference level at the *measurement channel* detector. Using this attenuator setting as a zero base, a second step of 35 db is then measured.

ELECTRONIC INSTRUMENTS— REQUIREMENTS AND DESCRIPTION

Microwave and some electronic equipment suitable for use in the dual channel measuring system are shown in Tables 1 through 14. Certain pieces of electronic equipment, however, were designed specifically for this application. These are described below.

SYNCHRONOUS DIFFERENTIAL NULL DETECTOR

The Weinschel Engineering Model ND-2 Synchronous Differential Null Detector is the heart of the dual channel insertion loss system. This instrument was designed to display the amplitude balance between two synchronous 1 kc signals. Many features such as logarithmic amplifiers and a low noise synchronous detector are used so that the balance can be made accurately and conveniently. This balance is maintained over a wide amplitude range providing that the ratio of the two signals remains constant. A difference in phase or a change in the ratio of the two signals, however, will produce an unbalance indication. At a typical setting of sensitivity, the full scale indication on the ND-2 is equivalent to a change of ± 0.02 db in the *measurement channel* rf signal level. Under ideal operating conditions, this full scale deflection can be set as high as ± 0.001 db.

A block diagram of the ND-2 is shown in Figure 6. The *reference channel* input signal is applied to the constant amplitude phase shift network, amplified and then fed to the adder circuit where its vector value is compared with that of the signal from the *measurement channel*. The resulting unbalance signal is fed to the lin-log amplifier, a harmonic rejection trap and a sensitivity control.

The gain of the lin-log amplifier is approximately logarithmic to provide maximum sensitivity for small signals close to the null and to prevent the amplifier from being overloaded by large unbalance signals. The signal from this amplifier is then rectified and powers a meter which gives a coarse indication of balance. This meter is used to make the initial phase and amplitude adjustments.

The same output signal from the lin-log amplifier is applied to the synchronous detector which uses as a reference a square wave *reference channel* signal from the output of the phase shift network. A meter which is used for the final balance adjustments

Figure Number 5: Model ND-2, Synchronous Differential Null Detector

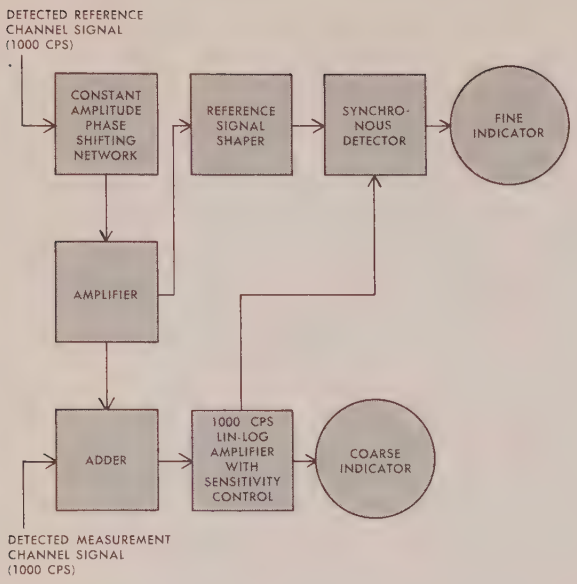


Figure Number 6: Block Diagram of the Weinschel Synchronous Differential Null Detector, Model ND-2

is connected across the output of the synchronous detector. The synchronous detector increases the range of measurements because it responds to signal voltages but it does not react appreciably to noise.

ATTENUATOR CALIBRATOR

The Model BA-5 Attenuator Calibrator in the *measurement channel* is used as the measurement standard and is, therefore, one of the most important instruments in the system. It consists of an accurate audio substitution attenuator standard, a bolometer preamplifier, a high gain tuned amplifier and a detector with an output meter. In order to eliminate any non-linearity of the amplifier as a possible source of measurement error the audio substitution attenuator precedes the amplifier. The amplifier then operates at a substantially constant level during any one measurement. The output meter on the BA-5 is used only to monitor the level of the *measurement*

Figure Number 7: Model BA-5, Attenuation Calibrator

channel to insure that the system is operating in the proper range. A signal from the output of the BA-5 is used by the ND-2 Synchronous Differential Null Detector in balancing the two channels of the system.

A bolometer bias current supply is included in the Model BA-5. This biasing circuit has a protective crystal diode in parallel with the bolometer to limit the peak discharge current and thus protect the bolometer from transients when applying or disconnecting the ac power to the instrument or connecting or disconnecting the bolometer to the instrument.

RF SOURCE

The rf power source must be stable in both frequency and power output so that no change in the characteristics of the unit under test will occur during the measurement. The dual channel technique reduces the effect of any change in source output but if the unit under test is non-linear or frequency sensitive, its measured value may change. A change

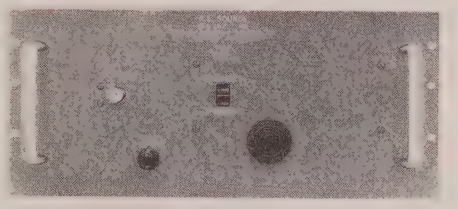


Figure Number 8: Model MS-8, RF Source

in the rf frequency may also unbalance the system if the bolometers are critically tuned.

The rf power source must be 100% square wave modulated at a frequency of 1 kc. It is important that this frequency be very stable since tuned amplifiers are used in both channels. A very small change in the modulation frequency can result in a phase unbalance in the signals applied to the Synchronous Differential Null Detector.

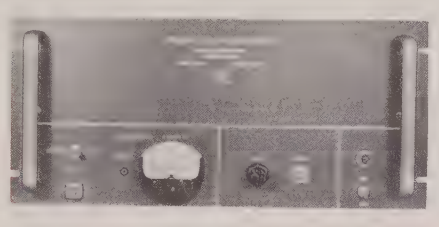
It is recommended that the appropriate Weinschel Engineering RF Source, MS-8, -9, -10, -11, -12, -13, -16 or -17 be used with the Model MO-3 or MO-5 Power Supplies since these supplies use a tuning fork stabilized 1 kc modulator and the voltages are closely regulated. At higher frequencies one of the other sources shown in Table 1 can be used with the tuning fork stabilized oscillator in the Weinschel Engineering Model MO-1 Modulator. The output of the MO-1 is sufficient to modulate most test oscillators. The modulation frequency of either the MO-1, MO-3, or MO-5 is held to 1000/ $\pm$ 0.1 cps.

APPLICATION NOTE NO. 4

REFERENCE CHANNEL AMPLIFIER

The linear range of the *reference channel* is not too critical since it operates at substantially constant level throughout the measurement. Convenience, however, dictates a fairly wide dynamic range and a variable gain to allow easy adjustment of the signal level at the output of the *reference channel*. It is necessary, however, that the gain of this channel be very stable. The Weinschel Engineering Model BA-1 Bolometer Amplifier fulfills these requirements.

Figure Number 9: Model BA-1, Bolometer Amplifier



CONCLUSION

A system has been described for the measurement of insertion loss up to 35 db with an accuracy of better than 0.02 db per 10 db.* This measurement can be made at frequencies above 1 mc for which power sources and bolometers are available. Also described is the application of Weinschel Engineering's Attenuator Calibrator, Model BA-5 and Synchronous Differential Null Detector, Model ND-2. The Model ND-2 was specifically designed for this measuring system.

To increase the range of insertion loss measurements, partial rf substitution can be used providing that the source has sufficient power output. For example, if the source has an output of 200 mw, the range can be extended 20 db to a total of 55 db, with only a slight deterioration in accuracy.

* Or 0.01 db whichever is greater.

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1.* Weinschel Engineering Application Note No. 1, "Single Channel Insertion Loss Test Set".

2.* G. U. Sorger and B. O. Weinschel, "Precise Insertion Loss Measurements Using Imperfect Square Law Detectors and Accuracy Limitations Due to Noise," pp. 55-68, IRE Transactions on Instrumentation, October 1955, reprinted as Weinschel Engineering Note No. 1.

3.* B. O. Weinschel, "Insertion Loss Test Sets Using Square Law Detectors," pp. 160-64, IRE Transactions on Instrumentation, October 1955, reprinted as Weinschel Engineering Note No. 2.

*Available on request from Weinschel Engineering.

TABLE 1: R. F. SOURCES

Frequency Range (GC)	Manufacturer*	Model Number	Power Supply Required
0.05 — 0.25	Weinschel	MS-1	None
0.05 — 0.25	Weinschel	MS-12	Weinschel Model MO-3**
			Weinschel Model MO-5**
0.25 — 0.92	Weinschel	MS-2	None
0.25 — 0.92	Weinschel	MS-13	Weinschel Model MO-3**
			Weinschel Model MO-5**
0.90 — 2.00	Weinschel	MS-3	None
1.90 — 2.20	Weinschel	MS-8	Weinschel Model MO-3**
			Weinschel Model MO-5**
2.00 — 4.20	Weinschel	MS-4	Weinschel Model MO-3**
			Weinschel Model MO-5**
4.0 — 7.50	Weinschel	MS-10	Weinschel Model MO-3**
			Weinschel Model MO-5**
7.2 — 10.5	Weinschel	MS-11	Weinschel Model MO-3**
			Weinschel Model MO-5**
8.2 — 12.4	Varian	X-13	See Table 2
10.5 — 12.5	Weinschel	MS-16	Weinschel Model MO-5**
12.4 — 17.5	Varian	X-12	See Table 2
15.0 — 20.5	Weinschel	MS-17	Weinschel Model MO-5**
22.0 — 25.0	Raytheon	2K33B	See Table 2
22.0 — 25.0	Varian	VA-96	See Table 2
22.3 — 30.0	Raytheon	QKK-289	See Table 2
29.7 — 33.5	Raytheon	QKK-290	See Table 2
33.5 — 36.2	Raytheon	QKK-291	See Table 2
35.1 — 39.7	Raytheon	QKK-292	See Table 2
37.1 — 42.5	Raytheon	QKK-293	See Table 2
41.0 — 50.0	Raytheon	QK-294	See Table 2
50.0 — 60.0	Raytheon	QK-295	See Table 2

*See Code of Manufacturers, Table 15.
**Includes Modulator

TABLE 2: KLYSTRON POWER SUPPLIES

Manufacturer*	Model Number
PRD	815
Sperry	62A1
FXR	Z815B

* See Code of Manufacturers, Table 15.

TABLE 3: LOW PASS FILTERS

Cutoff Frequency (GC)	Manufacturer*	Model Number
.044	Sierra	184
.076	Sierra	184
.135	Sierra	184
.230	Sierra	184
.400	Sierra	184
.400	Bird	844
.500	Narda	3010-500
.7	H-P	360-A
1.0	Narda	3010-1000
1.2	Bird	819-1200
1.2	H-P	360-B
2.1	Narda	3010-2100
2.2	H-P	360-C
4.1	H-P	360-D
4.2	Narda	3010-4200

*See Code of Manufacturers, Table 15.

TABLE 4: COAXIAL AND WAVEGUIDE ATTENUATORS

COAXIAL		
Frequency Range (GC)	**Manufacturer***	**Model Number**
DC-1.0	Weinschel	Model 905 (Variable)
DC-1.0	Weinschel	Model 10 (Fixed)
DC-3.0	Weinschel	Model 50 (Fixed)
DC-5.0	Weinschel	Model 650 (Fixed)
1.0-12.4	Weinschel	Model 210 (Fixed)
1.0-12.4	Weinschel	Model 503 (Fixed)

WAVEGUIDE				
Frequency Range (GC)	**Manufacturer's* Model Number**			
	FXR	**H-P**	**Narda**	**PRD**
2.6 - 3.95	S-155-A	S-375-A	734	171
3.95 — 5.85	H-155-A	G-375-A	733	162
5.85 — 8.2	C-155-A	J-375-A	732	161
7.05 — 10.0	W-155-A	H-375-A	731	160
8.2 — 12.4	X-155-A	X-375-A	730	159
12.4 — 18.0	Y-151-A	P-375-A	729	189
18 0 — 26.5	K-151-A	K-375-A	728	190
26.5 — 40.0	U-151-A	R-375-A	V-727	191
33.0 — 50.0	Q-151-A		Q-727	
50.0 — 75.0	M-151-A		M-727	179
60.0 — 90.0	E-151-A		E-727	

*See Code of Manufacturers, Table 15.

TABLE 5: ISOLATORS

Manufacturer*	Model Number	Manufacturer*	Model Number
Rantec Airtron Kearfott Cascade Raytheon	Consult Manufacturer for Proper Model for Your Needs	Sylvania TRG Inc. Micromega Narda PRD FXR	Consult Manufacturer for Proper Model for Your Needs

* See Code of Manufacturers, Table 15.

TABLE 6: FREQUENCY METERS

Frequency Range (GC)	Manufacturer's* Model Number			
	FXR	**H-P**	**Narda**	**PRD**
0.2 — 0.5			804	
0.250 — 1.0				587A
0.5 — 2.4			805, 806	
1.0 — 4.0	N410A	536A		
3.95 — 5.85	H410A	G532A		532
5.85 — 8.20	C410A	J532A		533
8.20 — 12.4	X410A	X532A	840	535
12.4 — 18.0	Y410A	P532A		536
18.0 — 26.5	K410A	K532A		537
26.5 — 40.0	U410A	R532A		538
33.0 — 50.0	Q410		Q807	
50.0 — 75.0	M410		M807	
60.0 — 90.0	E410		E807	

*See Code of Manufacturers, Table 15.

TABLE 7: SLOTTED LINES

COAXIAL		
Frequency Range (GC)	**Manufacturer***	**Model Number**
0375 — 3.0	Alford	1026B-16[1]
.1 — 4.0	Alford	2181-6[2]
.5 — 4.0	H-P	805-C
.45 — 4.0	Narda	230-N, 230-C, 230-5/8, 230-7/8, 230-SC
1.0 — 4.0	FXR	N-101-A[3]
1.0 — 4.0	PRD	215-A[3]
1.5 — 12.4	Narda	231-N, 231-C, 231-TNC[3]
3.0 — 12.0	H-P	806-B[3]
4.0 — 10.0	FXR	N-101-B[3]
4.0 — 10.0	PRD	205-A[3]

WAVEGUIDE				
Frequency Range (GC)	**Manufacturer's* Model Number**			
	FXR	**Narda**	**H-P**	**PRD**
2.60 — 3.95	S-101-A[3]	224[3]	S-810[3]	209-A[3]
3.95 — 5.85	H-101-A[3]	223[3]	G-810-B[4]	201-A[3]
5.85 — 8.2	C-101-A[3]	222[3]	J-810-B[4]	204-B[3]
7.05 — 10.0	W-101-A[3]	221[3]	H-810-B[4]	202-B[3]
8.2 — 12.4	X-101-A[3]	220[3]	X-810-B[4]	203-D[3]
12.4 — 18.0	Y-102-A	219[3]	P-810-B[4]	210-A
18.0 — 26.5	K-102-A	218[5]	K-815-B[4]	211-A
26.5 — 40.0	U-102-A[5]	V-217[5]	R-815-B[4]	212-A
33.0 — 50.0	Q-103-A[5]	Q-217[5]		
50.0 — 75.0	M-103-A[5]	M-217[5]		216
60.0 — 90.0	E-103-A[5]	E-217[5]		

* See Code of Manufacturer, Table 15.

[1] Requires one Type 1122C Type N Tapered Reducer.
[2] Requires one Type 2170 Type N Tapered Reducer.
[3] Requires Tuning Probe, See Table 8.
[4] Used with Universal Probe Carriage and Tuning Probe, See Table 8.
[5] Requires Detector Mount.

TABLE 8: PROBES

Freq. Range (GC)	Manufacturer*	Model Number
1.0 — 12.4	FXR	B-200-A tunable
1.0 — 12.4	PRD	250-A tunable
.9 — 18.0	Narda	229 tunable
3.0 — 18.0	H-P	444-A untuned
18.0 — 40.0	H-P	446-B untuned

* See Code of Manufacturers, Table 15.

TABLE 9: VSWR INDICATORS

Manufacturer*	Model Number
H-P	415-C
PRD	277B
FXR	B-812-A
Narda	441B

* See Code of Manufacturers, Table 15.

TABLE 10: TUNERS

COAXIAL TUNERS		
Frequency Range	**Manufacturer**	**Model Number**
40 MC — 400 MC	Weinschel	DS-109H
.20 GC — 2.0 GC	Weinschel	DS-109LL
.40 GC — 4.0 GC	Weinschel	DS-109L
75 GC — 10.0 GC	Weinschel	DS-109

WAVEGUIDE TUNERS				
Frequency Range (GC)	**Manufacturer's* Model Number**			
	H-P	**PRD**	**Narda**	**FXR**
2.60 — 3.95	S-870-A	309-A	964	S-311-A S-312-A
3.95 — 5.85	G-870-A	300-A	963	H-311-A H-312-A
5.85 — 8.20	J-870-A	305-A	962	C-311-A C-312-A
7.05 — 10.0	H-870-A	302-B	961	W-311-A W-312-A
8.2 — 12.4	X-870-A X-880-A	303-A	960	X-311-A X-312-A
12.4 — 18.0	P-870-A P-880-A	314-A	959	Y-311-A Y-312-A
18.0 — 26.5	K-870-A K-880-A	313-A	958	K-312-B
26.5 — 40.0	R-870-A R-880-A	312-A	V-957	U-312-B
33.0 — 50.0			Q-957	Q-312-B
50.0 — 75.0		323	M-957	M-312-B
60.0 — 90.0			E-957	E-312-B

* See Code of Manufacturers, Table 15.

TABLE 11: BOLOMETER MOUNTS

COAXIAL BOLOMETER MOUNTS			
Frequency Range (GC)	Manufacturer*	Model Number	Barretter Model Number
0.01 — 10	Weinschel	926[1]	943

WAVEGUIDE BOLOMETER MOUNTS					
Frequency Range (GC)	Manufacturer's* Model Number				
	FXR	H-P	Narda	PRD	Sperry
2.60 — 3.95	S-207A	S-485A	534	S6608	33S2
3.95 — 5.85	H-207A	G-485A	533	G6608	33C2
5.85 — 8.20	C-207A	J-485A	532	C6608	33G2
7.05 — 10.00	W-207A	H-485A	531	H6608	33H2
8.20 — 12.40	X-207A	X-485A	530	X6608	33X2
12.4 — 18.0	Y-205		529	620	
18.0 — 26.5	K-205			620F1	
26.5 — 40.0	U-205			618F1	
33.0 — 50.0	Q-206				
50.0 — 75.0	M-206				
60.0 — 90.0	E-206				

*See Code of Manufacturers, Table 15.

[1] This unit has a built-in noise suppressor equivalent to Weinschel Model 936N. It is fixed tuned and has a VSWR below 1.5 over the entire frequency range.

TABLE 12: BARRETTERS

Type	Description	DC Bias (MA)	Manufacturer's* Model Number					Special Features
			Weinschel	FXR	Narda	PRD	Sperry	
1	1N21	4.5		Z-220-C	N-610-B-4.5	610A		
2	1N21	8.75		Z-220-A	N-610-B		38B7	
2	1N21	8.25		Z-220-B				
3	1N21	8.75			N-610-B-100			100 ohms
4	.193" dia. .812" long	8.75			N-821-B		38B1	
5	1N26	4.5				614		12.4-26.5 GC
5	1N26	8.75		Z-221-A				12.4-40 GC
6	Modified	8.75		Z-221-B				26.5-40 GC
7	1N53	8.75		Z-222-A				26.5-90 GC
8	Special Mica Strip	4.5			N-603-4.5	631-C		0.5-10 GC
9	"	8.75			N-603			0.5-10 GC
10	"	4.5				617		18-40 GC
11	Miniature	8.75			N-604			8.2-18 GC
12	1N21	8.75			N-605			(Low Inductance) 1.1-10 GC
13	Special Disc		943					.01-10 GC Coax.

*See Code of Manufacturers, Table 15.

TABLE 13: DIRECTIONAL COUPLERS

COAXIAL		
Frequency Range (GC)	Manufacturer*	Model Number
225 — 460	Narda	3000-10
460 — 950	Narda	3001-10
950 — 2.0	Narda	3002-10
2.0 — 4.0	Narda	3003-10
4.0 — 8.0	Narda	3044-10
7.0 — 11.0	Narda	3045-10

WAVEGUIDE					
Frequency Range (GC)	Manufacturer's* Model Number				
	H-P	FXR	PRD	Narda	Sperry
2.6 — 3.95	S752C	S610C	409	1074-10	45S1
3.95 — 5.85	G752C	H610C	410	1073-10	45C1
5.85 — 8.2	J752C	C610C	411	1072-10	45G1
7.05 — 10.0	H752C	W610C	412	1071-10	45H1
8.2 — 12.4	X752C	X610C	408	1070-10	45X1
12.4 — 18.0	P752C	Y610C	413	1069-10	45U1
18.0 — 26.5	K752C	K610C		1068-10	45K1
26.4 — 40.0	R752C	U610C		V1067-10	45V1
50.0 — 75.0		M610C		M1067-10	

*See Code of Manufacturers, Table 15.

TABLE 14: DETECTOR MOUNTS

COAXIAL		
Frequency Range (GC)	Manufacturer* and Model Number	Crystal Type
0.01 — 10	H-P, Model 420A	Modified 1N26
0.01 — 1.0	PRD, Model 641	Sylvania 1N21
0.5 — 1.0	Am. Elect. Lab., Model C1000	Micro Assoc. MA408
1.0 — 10.0	Weinschel, Model 578	Micro Assoc. MA408

WAVEGUIDE										
Frequency Range (GC)	Manufacturer*, Model Number and Crystal Type									
	Aircom	Crystal Type**	PRD	Crystal Type**	Micro Assoc	Crystal Type**	FXR	Crystal Type**	H-P	Crystal Type**
3.95 — 5.85	157-C	1N23								
5.85 — 8.2	157-XC	1N23								
8.2 — 12.4	157-X	1N23			536C	1N23	X211A	1N23	X421A	1N26 (mod.)
12.4 — 18.0	157-KU	1N76	616A	1N78			Y205B	1N26	P421A	1N26 (mod.)
18.0 — 26.5	157-K	1N26	621	1N26	1039C	1N26	K205B	1N26		
26.5 — 40.0	157-KA	1N53			513E	1N53	U206B	1N53		
33.0 — 50.0	157-V	1N53					Q206B	1N53		
50.0 — 75.0	157-W	1N53			369	1N53	M206B	1N53		

*See Code of Manufacturers, Table 15.
**Sylvania Model Number listed.

TABLE 15: CODE OF MANUFACTURERS*

Abbreviation	Manufacturer's Name and Address	Abbreviation	Manufacturer's Name and Address
Aircom	Aircom, Inc. 48 Cummington Street Boston, Mass.	Micro Assoc.	Microwave Associates, Inc. Northwest Industrial Park Burlington, Mass.
Airtron	Airtron Division of Litton Industries 200 East Hanover Avenue Morris Plains, N. J.	Micromega	Micromega Corp. 4134 Del Rey Avenue Venice, Calif.
Alford	Alford Manufacturing Company 299 Atlantic Ave. Boston, Mass.	Narda	Narda Microwave Corp. Plainview, N. Y.
Am. Elect. Lab.	American Electronics Lab., Inc. 121 North 7th Street Philadelphia 6, Pa.	PRD	PRD Electronics 202 Tillary Street Brooklyn, N. Y.
Bird	Bird Electronics Corp. 30303 Aurora Road Cleveland 39, Ohio	Rantec	Rantec Corp. Craftsman Center Calabasas, Calif.
BJ Electronics	BJ Electronics, Division of Borg-Warner Corp. 3300 Newport Boulevard Santa Anna, Calif.	Raytheon	Raytheon Co. Microwave and Power Tube Division Foundry Avenue Waltham 54, Mass.
Cascade	Cascade Research Division, Lewis & Kaufman Electronics Corp. 5245 San Fernando Road, W. Los Angeles, Calif.	Sierra	Sierra Electronics Corp., Division of Philco Corp. 3885 E. Bohannon Drive Menlo Park, Calif.
FXR	FXR, Division of Amphenol Borg Electronics Corp. 33 E. Franklin Street Danbury, Conn.	Sperry	Sperry Microwave Electronics Co., Division of Sperry Rand Corp. P.O. Box 1828 Clearwater, Florida
H-P	Hewlett-Packard Co. 1501 Page Mill Road Palo Alto, Calif.	TRG	TRG Inc. 2 Aerial Way Syosset, N. Y.
Kearfott	Kearfott Division, General Precision, Inc. 14844 Oxnard Street Van Nuys, Calif.	Varian	Varian Associates 611 Hansen Way Palo Alto, Calif.

* This list does not constitute an endorsement

WEINSCHEL ACCESSORIES

Weinschel Engineering produces a complete line of precision accessories for use with the Dual Channel Insertion Loss Test Set that has been described in the Application Note. Included among these accessories are both coaxial and waveguide noise suppressors, coaxial double stub tuners, bolometer mounts, and fixed and variable coaxial attenuators.

All Weinschel instruments and accessories are designed and manufactured to meet the most exacting requirements. Your assurance of quality and precision is a three-step inspection program. All purchased components and materials are inspected as they are received at Weinschel, and all instruments and components are inspected during various stages of manufacture. Completed items must then pass a rigid final inspection which is followed by careful calibration on the most precise measurement instrument available.

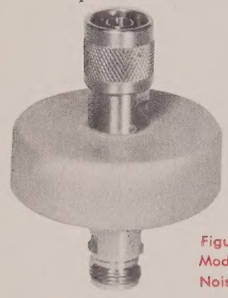

Figure Number 10:
Model 936N, Coaxial
Noise Suppressor

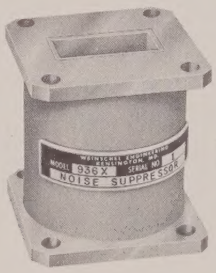

Figure Number 11:
Model 936X, Waveguide
Noise Suppressor

For the utmost in reliability and precision, a complete system of Weinschel instruments and accessories is unsurpassed.

We invite you to write for complete specifications on Weinschel precision accessories.

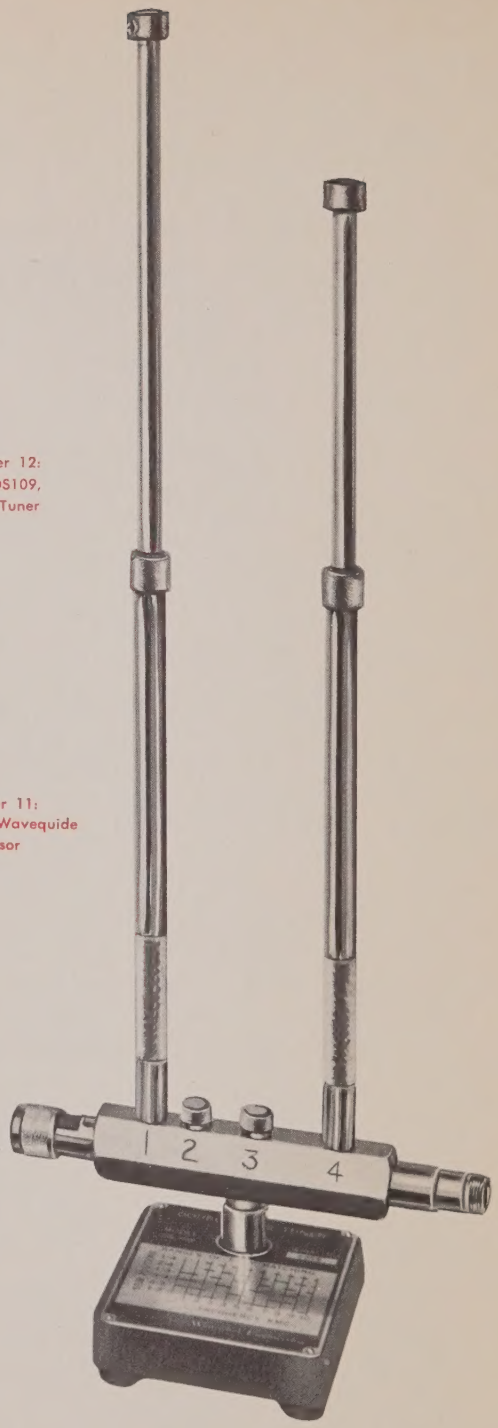

Figure Number 12:
Model DS109,
Double Stub Tuner

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